

**Multi-Phased Remedial Investigation (RI)
of Surface and Subsurface Contamination of Soldier Creek
at Tinker AFB, Oklahoma
U.S. Air Force Installation Restoration Program**

FINAL

REMEDIAL INVESTIGATION REPORT

VOLUME 1

FEBRUARY 1993

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SOLDIER CREEK RI/FS (NPL Site)
Prepared for: Tinker Air Force Base through
U.S. Army Corps of Engineers
Tulsa District

**FINAL
REMEDIAL INVESTIGATION REPORT
TINKER AFB - SOLDIER CREEK RI/FS**

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TINKER AIR FORCE BASE
through
TULSA DISTRICT CORPS OF ENGINEERS
CONTRACT NO. DACA56-89-C-0062**

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EXECUTIVE SUMMARY

This report presents the results of Phase I and Phase II of the remedial investigation (RI) conducted at the Soldier Creek Site at Tinker Air Force Base (AFB) in June and July 1990, and June 1991. The purpose of Phase I and Phase II of the RI was to evaluate the nature and extent of the threat posed by the presence, release, or potential release of hazardous substances at the Soldier Creek Site and to gather data to support the development and evaluation of remedial alternatives.

Tinker AFB is southeast of Oklahoma City in central Oklahoma. The main portion of Soldier Creek is to the east of Tinker AFB, however, two tributaries (West and East Soldier Creeks) originate on the Base. The Soldier Creek Site, a National Priorities List site, includes Soldier Creek, its tributaries, and any area underlying or adjacent to the waterway which may be contaminated by the migration of hazardous substances, pollutants, or contaminants from Tinker AFB (EPA, 1988b). Tinker AFB conducted the RI at the Soldier Creek Site under provisions of the Federal Facility Agreement between the U.S. Air Force, the Oklahoma State Department of Health, and Region VI of the U.S. Environmental Protection Agency under the U.S. Air Force's Installation Restoration Program.

Previous investigations have focused on three aquifer zones in the northeast corner of Tinker AFB, the perched aquifer, top of regional aquifer zone, and regional aquifer zone (Garber-Wellington Aquifer). The aquifer zones have average depths below the ground surface of 15, 30, and 110 feet, respectively. The regional groundwater flow direction in the Garber-Wellington is to the southwest. Groundwater in the perched aquifer flows semi-radially to the northwest, north, northeast, and east, from a groundwater high under Building 3001 that extends to the northeast toward the Industrial Wastewater Treatment Plant (IWTP). Groundwater in the top of regional aquifer zone flows to the southwest under Building 3001. However, because of a groundwater high under East Soldier Creek and part of Main Soldier Creek, groundwater in the top of regional aquifer zone flows to the east, north, and northeast near the northeast corner of Tinker AFB. Because of a groundwater high near the northeast corner of Tinker AFB, groundwater in the regional aquifer zone appears to flow to the west, east, and northeast.

One hundred and seventy-two composite sediment samples and 58 grab sediment samples were collected during Phase I and II of the RI. The composite sediment samples were analyzed for semi-volatile organics on the Target Compound List (TCL) and metals and cyanide on the Target Analyte List (TAL) in Phase I; semi-volatile organics on the TCL and metals (antimony, cadmium, chromium, lead) and cyanide on the TAL were analyzed during Phase II. The grab sediment samples collected in Phase I and II of the RI were analyzed for volatile organics on the TCL.

The Phase I and II sediment analytical results indicated the presence of volatile and semi-volatile organics, and inorganics at various concentrations along Soldier Creek.

Forty-eight composite and 48 grab surface water samples were collected during Phase I and II of the RI. The composite surface water samples were analyzed for semi-volatile organics on the TCL and metals and cyanide on the TAL in Phase I; metals (antimony, cadmium, chromium, lead) and cyanide on the TAL were analyzed during Phase II. The composite surface water samples were also analyzed for alkalinity, hardness, chemical oxygen demand, total suspended solids, 5-day biochemical oxygen demand, and total organic carbon in Phase I and II of the RI. Temperature, specific conductivity, dissolved oxygen, and pH were measured during the field activities. The grab surface water samples collected in Phase I and II were analyzed for volatile organics on the TCL.

The Phase I and II surface water analytical results indicated the presence of volatile and semi-volatile organics (Phase II samples were not analyzed for semi-volatiles) and inorganics at various concentrations along Soldier Creek.

Sampling results from Phase I of the RI and data from 130 monitoring wells previously sampled were used to evaluate the nature and extent of groundwater contamination at the Soldier Creek Site. Previous groundwater sampling results were obtained from the IWTP Remedial Investigations report (Tulsa COE, 1991a) and the Off-Base Groundwater Investigations Northeast of Base report (Tulsa COE, 1991b).

Volatile organic, semi-volatile organic, and inorganic contaminants were detected in all three aquifer zones at various concentrations in on-base and off-base wells.

The potential migration pathways at the Soldier Creek Site include infiltration and direct migration through surface and subsurface soil, sediment, and bedrock; groundwater transport; erosion and runoff; interaction between site aquifers; and interaction between the perched aquifer, top of regional aquifer zone, and Soldier Creek.

The primary potential sources of contamination from Tinker AFB at the Soldier Creek Site include on-base storage tanks and pits, and on-base and off-base spills. A total of 13 industrial outfalls and storm drains are known to have discharged directly to East and West Soldier Creeks on Tinker AFB (NUS, 1989). All of the connections between the outfalls and the industrial waste lines were closed in 1990. The storm drains are still active. Additional off-base industrial outfalls and storm drains, downstream on East and West Soldier Creek and up and downstream along the main stream, discharge flows from the surrounding area.

Several past and current potential sources of contamination at Tinker AFB were documented in the Building 3001 RI report (Tulsa COE, 1988a) and IWTP RI report (Tulsa COE, 1991a). These sources may be indirect sources of contamination to Soldier Creek through surface runoff or from perched aquifer zone groundwater discharge to the creek.

The Soldier Creek Site survey conducted during Phase I of the RI indicated that several potential off-base contamination sources also exist, including, but not limited to service stations, dry cleaners, and other industrial service and manufacturing facilities along Douglas Boulevard and Southeast 29th Street.

Based on risk calculations contained in the Soldier Creek Site Risk Assessment report (BVWST, 1993a), exposure to chemicals of concern in surface water and sediments has a low potential carcinogenic and noncarcinogenic risk in all scenarios. Therefore, no further investigation of sediment and surface water is deemed necessary.

Exposure to chemicals of concern in each portion of the aquifer system at the Soldier Creek Site results in potential carcinogenic risks greater than 1×10^{-6} (one in one million) for all scenarios. The hazard index for noncarcinogenic risks for all current exposures, except on-base workers who shower with perched aquifer water (a

scenario which is not occurring) is less than one (an acceptable level). However, the hazard index for noncarcinogenic risks for several future scenarios does exceed one. Although Soldier Creek may recharge the top of regional aquifer zone, and therefore may act as a contaminant transport mechanism, the low concentration of contaminants detected in Soldier Creek sediment and surface water indicate that little contamination may have been introduced into any groundwater aquifer zone via Soldier Creek. In addition, contaminant migration through Soldier Creek to the aquifer zones would be a significantly slower contaminant transport route compared to contaminant migration due to advective flow within the Soldier Creek Site aquifer zones.

The following are recommendations associated with the Soldier Creek Site:

- The hydrogeology at the Soldier Creek Site is complex. Groundwater contouring and analysis of the site aquifer zones has been conceptual to this point. All three aquifer zones should be characterized in greater detail through computer modeling of the site hydrogeology.
- Groundwater analytical results from several off-base wells indicate that there may be contamination in the aquifer system from off-base sources. During the RI, many off-base sources of potential contamination other than Tinker AFB were identified. These potential off-base sources should be evaluated to determine their contribution, if any, to the contamination of Soldier Creek Site groundwater, surface water, and sediment.
- Exclude groundwater underlying Soldier Creek and its drainage basin from the Soldier Creek FS and address the groundwater as a separate issue. The reason for this is two-fold. First, contaminant transport calculations indicate that very little contamination from Soldier Creek sediment is migrating downward to potentially contribute to contaminant concentrations found in the underlying top of regional aquifer zone. Second, the complexity of the hydrogeology at the Soldier Creek Site and the contribution of off-base sources to existing site contamination is not completely understood.

- Remedial technologies and alternatives associated with surface water and sediment remediation should be evaluated in the Soldier Creek Site Feasibility Study Initial Screening of Alternatives report and the Feasibility Study.

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ACRONYMS AND ABBREVIATIONS

AFLC	Air Force Logistics Command
Ag	Silver
AFB	Air Force Base
As	Arsenic
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
Ba	Barium
BEHP	Bis(2-ethylhexyl)phthalate
BOD ₅	5-Day biochemical oxygen demand
BNAs	Acid, base/neutral extractables
BTEX	Benzene, toluene, ethylbenzene, and xylene
BVWST	B&V Waste Science and Technology Corp.
C	Degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
Cd	Cadmium
CLP	Contract Laboratory Program
COD	Chemical oxygen demand
cm/s	Centimeters per second
Cr	Chromium
CRQL	Contract Required Quantitation Limit
Cu	Copper
DCE	Dichloroethene
DO	Dissolved oxygen
Eh	Redox potential
EPA	U.S. Environmental Protection Agency
EWI	Equal-Width Increment
F	Degrees Fahrenheit
Fe	Iron
FFA	Federal Facilities Agreement
FS	Feasibility Study
ft	Feet
ft/s	Feet per second
ft ³ /s	Cubic feet per second
gm/cm	Gram per centimeter
gpd/ft	Gallons per day per foot
gpm	Gallons per minute
HKS	Harry Keith & Sons, Inc.
IDL	Instrument detection limit
IRP	Installation Restoration Program
IWTP	Industrial Wastewater Treatment Plant
Koc	Soil Adsorption Coefficient

ACRONYMS AND ABBREVIATIONS (Continued)

Kow	Log Octanol-Water Partition Coefficient
lb/ft ³	Pounds per cubic foot
MCL	Maximum Contaminant Level
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MI	Mobility Index
mm Hg	Millimeters of Mercury
Mn	Manganese
mph	Miles per hour
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
Ni	Nickel
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NUS	NUS Corporation
ONHI	Oklahoma Natural Heritage Inventory
OSDH	Oklahoma State Department of Health
OWRB	Oklahoma Water Resources Board
Pb	Lead
PCB	Polychlorinated biphenyls
PCE	Tetrachloroethene
ppm	Parts per million
RAS	Routine analytical services
RI	Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act
SAS	Special analytical services
Se	Selenium
STP	Sanitary Treatment Plant
TAL	Target Analyte List
TCE	Trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total dissolved solids
TIC	Tentatively Identified Compound
TOC	Total organic carbon
TSS	Total suspended solids
Tulsa COE	U.S. Army Corps of Engineers, Tulsa District
ug/kg	Micrograms per kilogram
ug/L	Micrograms per liter
umhos/cm	Micromhos per centimeter

ACRONYMS AND ABBREVIATIONS (Continued)

USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UST	Underground storage tank
VOC	Volatile organic compound
Zn	Zinc

1.0 INTRODUCTION

This report summarizes the activities conducted during Phase I and II of the remedial investigation for the Tinker Air Force Base - Soldier Creek Remedial Investigation (RI)/Feasibility Study (FS) project. This section includes a description of the purpose of the RI report, a presentation of the authority for the work, site location and description, site history, and previous investigations and reports.

1.1 Purpose of Remedial Investigation Report

The RI report presents the site background, the RI field activities, nature and extent of contamination, contaminant fate and transport, risk assessment (included as a separately bound document), and summary and conclusions for the Soldier Creek Site. This RI report was completed in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA, 1991a), the U.S. Environmental Protection Agency's (EPA's) "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA, 1988a), and the "Air Force Installation Restoration Program Management Guidance" (AFLC, 1989).

1.2 Authority for the Work

On December 9, 1988, the U.S. EPA Region VI, the Oklahoma State Department of Health (OSDH), and the U.S. Department of the Air Force, Tinker Air Force Base (AFB) signed a Federal Facilities Agreement (FFA) (Administrative Docket Number NPL-U3-2-27) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Section 120 and the Superfund Amendments and Reauthorization Act of 1986 (SARA). The intent of this agreement is to ensure that the past and present activities at Building 3001 and Soldier Creek, National Priorities List (NPL) sites, are thoroughly investigated and appropriately remediated to protect the public health, welfare, and the environment. The FFA establishes requirements for the performance of the RI and the FS in accordance with CERCLA. In addition, the FFA establishes procedures and schedules for developing, implementing, monitoring, documenting, and approving response actions at both the Building 3001 and Soldier Creek Sites, in accordance with CERCLA and the NCP (EPA, 1991a), and Superfund guidance and policy. The agreement establishes procedures for remedial actions and specifies that Tinker AFB

will establish and maintain an administrative record that will include all documents that form the basis for the initiation of a response action at both the Building 3001 and Soldier Creek Sites (EPA, 1988b).

1.3 Site Location and Description

Tinker AFB is located in Oklahoma County to the southeast of the metropolitan area comprised of Oklahoma City, Del City, and Midwest City in central Oklahoma. The Base is approximately bounded by Sooner Road to the west, Interstate 40 to the north, Douglas Boulevard to the east, and Southeast 74th Street to the south as illustrated on Figure 1-1 (page 1-3). Soldier Creek is located mainly to the east of the Base and flows to the north from its headwaters located just to the north of Southeast 59th Street, to its confluence with Crutcho Creek approximately six miles downstream. Two tributaries, referred to as East Soldier Creek and West Soldier Creek, are located on the northeastern portion of Tinker AFB as shown on Figure 1-2 (page 1-4).

The Soldier Creek Site includes Soldier Creek, its tributaries, and any areas underlying or adjacent to the waterway that may be contaminated by the migration of hazardous substances, pollutants, or contaminants from Tinker AFB (EPA, 1988b). For the purposes of the Soldier Creek RI, the study area primarily consisted of the tributaries that receive discharges or runoff from Tinker AFB (West and East Soldier Creeks) and the main branch of Soldier Creek from its headwaters to where it flows beneath East Reno Avenue.

Soldier Creek and its tributaries receive surface runoff from an area consisting of approximately 9,000 acres. Areas on Tinker AFB that contribute runoff or discharge to Soldier Creek and its tributaries include the Building 3001 Site and the Industrial Wastewater Treatment Plant (IWTP), which comprises a total contributing area of approximately 300 acres. The Building 3001 Site includes the Building 3001 complex, two adjacent underground storage tank areas (the North Tank Area and the Southwest Tank Area), and the surrounding areas encompassed by the lateral extent of the contaminant plume (EPA, 1988b). The Building 3001 complex consists of an

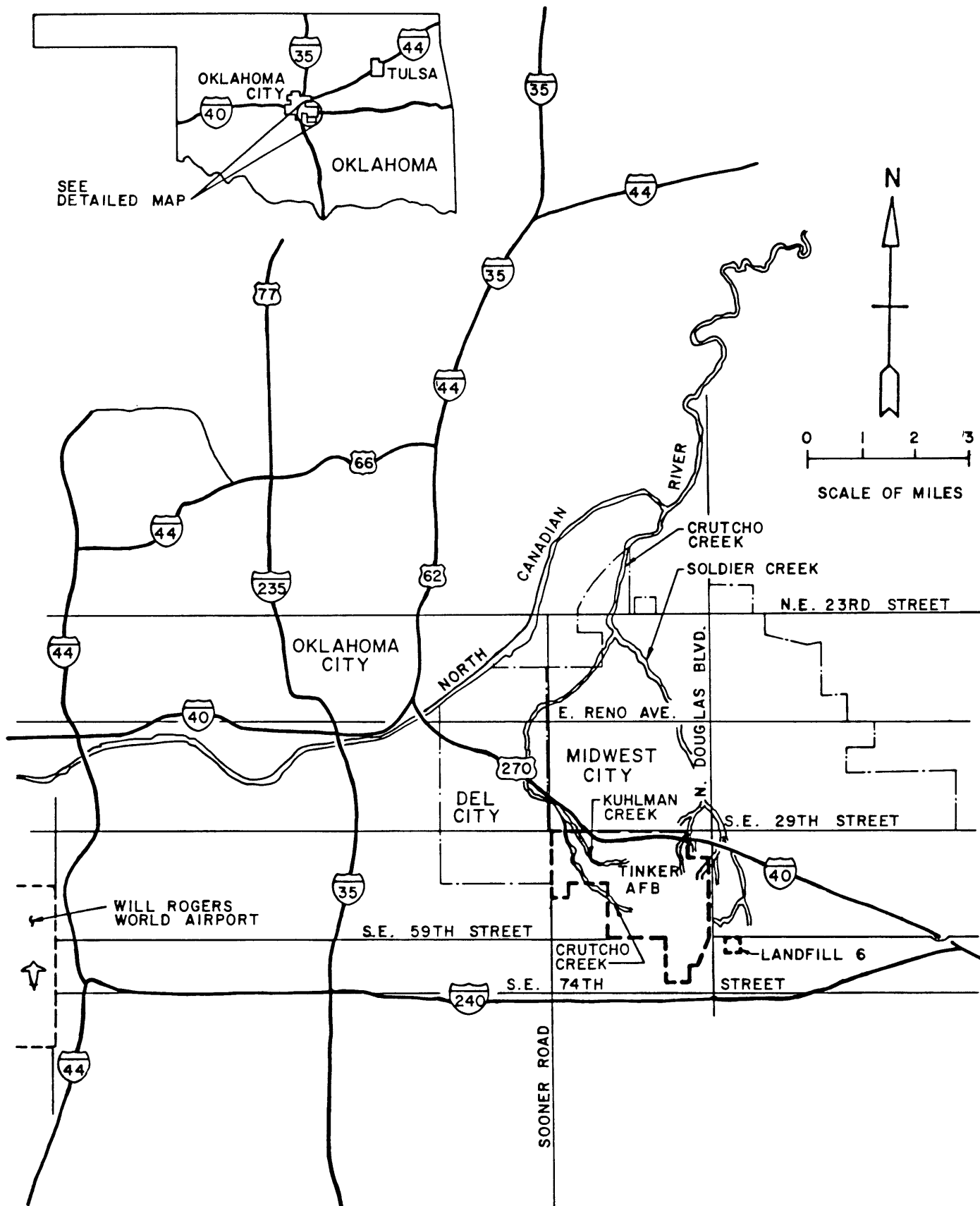
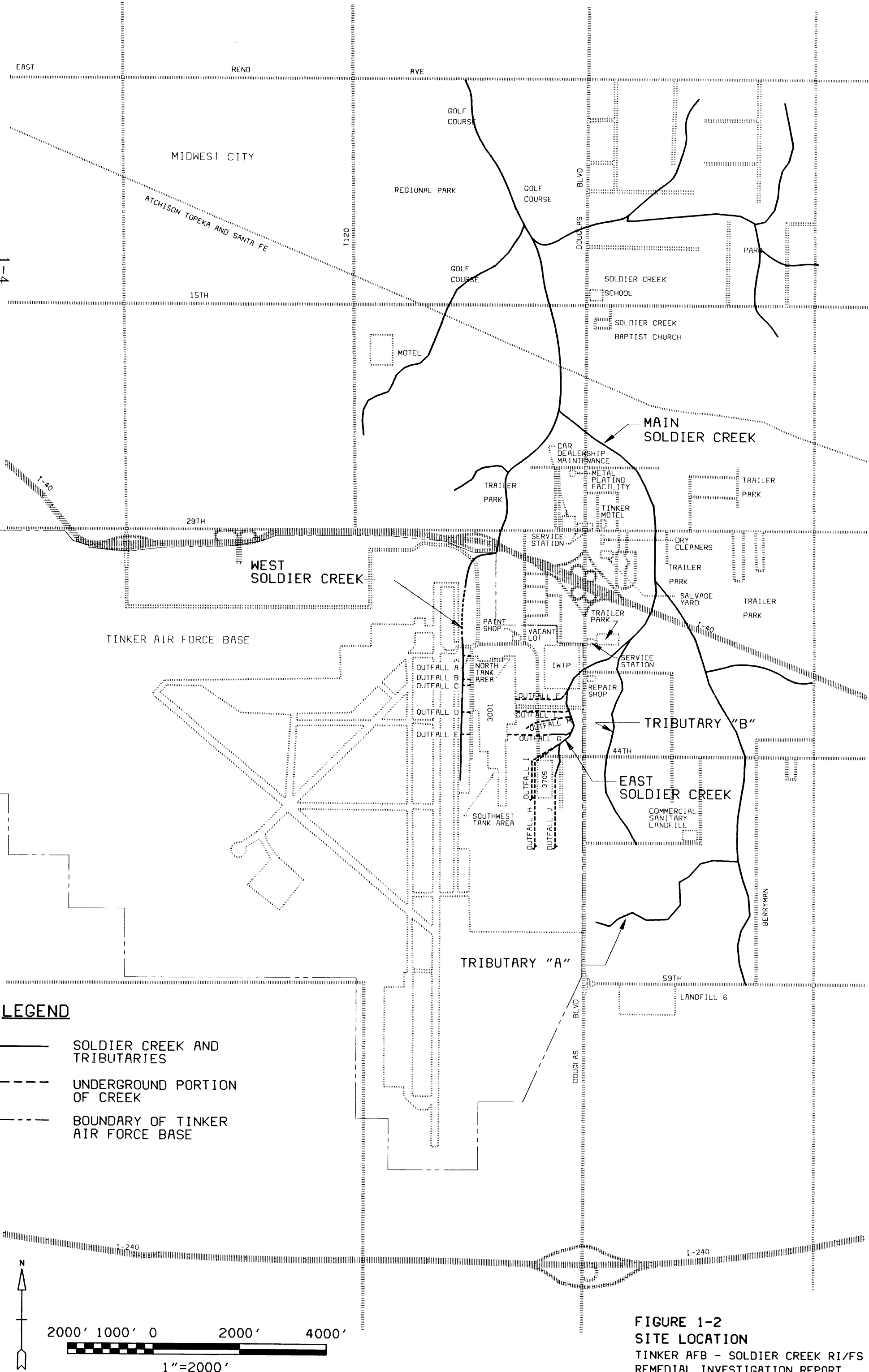


FIGURE 1-1
 SITE VICINITY
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT



aircraft overhaul and modification complex to support the mission of the Oklahoma City Air Logistics Center. The primary activities at Building 3001 include the following:

- Disassembly, degreasing, cleaning, and inspection of aircraft and engine parts and components.
- Plating, painting, heat treating, and testing of metal parts and components.
- Assembly and repairing of accessories including electrical, valve and governor, gear box, tubing and cable, fuel controls, nozzles, pumps, and bearings.
- Assembly, testing, and packaging of aircraft and aircraft components.

The North Tank Area contains abandoned underground storage tanks for fuel oil, diesel fuel, and gasoline, and is located north of Building 3001. The Southwest Tank Area contains abandoned fuel and solvent tanks, and is located to the southwest of Building 3001 (Tulsa COE, 1988a).

The IWTP, located in the northeastern portion of the Base as shown on Figure 1-2 (page 1-4), receives industrial process discharge waters from the Building 3001 complex via a series of underground lines. Once received at the plant, these waters are treated and combined with treated sanitary wastewater prior to discharge to East Soldier Creek under a National Pollutant Discharge Elimination System (NPDES) permit with the Oklahoma Water Resources Board (NUS, 1989).

1.4 Site History

Tinker AFB was activated in March 1942 under the name of the Midwest Air Depot. During World War II, the depot was responsible for reconditioning, modifying and modernizing aircraft, vehicles and equipment. During this period, the civilian employment peaked at 14,925 employees.

At the conclusion of World War II, the Douglas Aircraft Plant located east of the north-south runway was annexed to the Base. Tinker AFB became involved in jet engine overhaul and later began modifying aircraft in a program to rebuild the nation's airpower. In 1948, Tinker AFB became a worldwide repair depot for several aircraft and a multitude of other weapons and engines. The level of activity has fluctuated during the history of the Base, however the primary mission has not changed and Tinker AFB is still a major industrial complex for overhauling, modifying, and repairing military aircraft, aircraft engines, and accessory items.

The Base has made several land acquisitions besides the Douglas Aircraft Plant. During 1951, the Air Force acquired a parcel of land located one half mile east of the southeast corner of Tinker AFB. The area was named the Oklahoma City Air Force Station and was supported by Tinker AFB. In 1956, the area officially became a separate entity; however support was still provided by Tinker AFB. The area was initially occupied by the 33rd Air Division and is presently occupied by the Engineering Installations Center, part of the Air Force Communications Command. In 1954, the Base acquired a parcel of land south of the Southeast 59th Street boundary to extend the existing main runway. The land acquisition consisted of approximately 300 acres. During 1956, the Base acquired additional land in the same area completing the parcel of land south of Southeast 59th Street presently within Tinker AFB jurisdiction. In 1957, a 638 acre tract of land immediately west of the original air base was acquired to develop permanent military housing and community support facilities. In 1975, the Base acquired an additional 187 acres of land situated contiguous to the west side of Air Depot Boulevard between Southeast 59th Street and Southeast 44th Street (Engineering Science, 1982).

As part of the overall Air Force Installation Restoration Program (IRP), Tinker AFB began a preliminary assessment of previously used waste disposal sites in 1981 (EPA, 1988b). As a result of a basewide sampling program in 1983 which detected trichloroethene in the groundwater, extensive investigations were conducted in and around Building 3001. These investigations identified chromium as an additional chemical of concern in the groundwater. On July 22, 1987, the Building 3001 Site and the Soldier Creek Site were added to the NPL. On December 9, 1988, EPA Region VI, the OSDH, and the United States Air Force, Tinker AFB signed the FFA under CERCLA Section 120 to "ensure that the environmental impacts associated

with past and present activities at the [Building 3001 and Soldier Creek Sites] are thoroughly investigated and appropriate remedial action [are] taken as necessary to protect the public health, welfare, and the environment" (EPA, 1988b). The specific activities to be performed under the FFA include, but are not limited to, completion of RI/FS activities at the Soldier Creek Site (EPA, 1988b).

The Building 3001 Site and adjacent underground storage tank areas have undergone extensive investigations to determine the nature and extent of contamination in and around this complex. In addition, a risk assessment (Tulsa COE, 1988b) and an RI/FS (Tulsa COE, 1988a and 1989a) have been completed for the Building 3001 Site. The North Tank Area investigation was reported in the Building 3001 documents and is now identified as a separate operable unit from Building 3001. The Southwest Tank Area is presently being investigated in accordance with underground storage tank regulations.

Investigation of possible sediment and surface water contamination of Soldier Creek began in 1984 (Radian, 1985a). Additional information on investigations conducted to determine the extent of contamination in Soldier Creek is presented in Subsection 1.5, Previous Investigations and Reports. Based on the results of the investigations of Soldier Creek, a removal action was performed on on-base portions of East and West Soldier Creeks in early 1986. Visibly contaminated sediments were removed and disposed in an approved hazardous waste landfill.

1.5 Previous Investigations and Reports

Prior to initiation of activities for planning and completing the Soldier Creek RI in 1989, a variety of investigations pertaining to the Soldier Creek Site have been conducted by a number of organizations since 1984. A summary of these previous investigations and pertinent reports is shown in Table 1-1 (page 1-8). A description of each of these previous investigations follows including, if known, the purpose of each investigation, sampling locations, pertinent analytical data, sample methodology and conclusions. Each subsection is titled according to the organization that performed the sampling and the media sampled.

TABLE 1-1
SUMMARY OF PREVIOUS INVESTIGATIONS
TINKER AFB - SOLDIER CREEK R/FS
REMEDIAL INVESTIGATION REPORT

REFERENCE DOCUMENT	SAMPLER	DATES	SAMPLE MEDIUM	SAMPLE ANALYSIS	ANALYZED BY
Installation Restoration Program Phase II Confirmation/Quantification Stage 2 Final Report for Tinker AFB, Oklahoma (Radiation, 1984)	Radian Corporation	6/84 - 7/84	Sediment	Metals, Fluoride, Cyanide, Polychlorinated Biphenyls (PCBs), Pesticides, Phenols, Nitrates, and Total Organic Carbon (TOC)	Radian Laboratories
An Evaluation of the Effects of Wastewater Discharge from TAFB on Water Quality of Crutcho & Soldier Creeks (EPA, 1984)	EPA	10/84, 11/84	Sediment	Metals, Volatile Organic Compounds (VOCs), Acid, Base/Neutral Extractables (BNAs)	EPA Laboratory
Site Investigation Report (HKS, 1985)	Harry Keith & Sons, Inc.	10/85	Water	Metals, VOCs, BNAs, Water Quality Data Nitrate, Cyanide, Phenols	Environmental Laboratories Inc.
"Sample Results" (1) Report (HKS, 1986)	Harry Keith & Sons, Inc.	4/86 & 5/86	Sediment	Metals, BTX, VOCs	Environmental Control Laboratory
"Sample Results" (1) Report IWTP & STP Discharges (Tinker AFB, 1987a)	Tinker AFB	3/87 - 9/87	Water	VOCs	METLAB
"Sample Results" (1) Report (OSDH, 1987)	Oklahoma State Department of Health	6/87	Sediment Water	Metals Metals, VOCs	Oklahoma State Department of Health Laboratory
NPDES Analytical Results (Tinker AFB, 1987b)	Tinker AFB	9/86 - 7/87	Water	Water Quality Data, pH, Total Suspended Solids (TSS), Oil and Grease	Analab of Texas
Building 3001 Remedial Investigations, Volumes I and II (Tulsa COE, 1988a and 1988d);	Tulsa COE	5/86 - 4/87	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, Tentatively Identified Compounds (TICs)	U.S. Corps of Engineers, Southwest Division Laboratory
Building 3001 Supplemental Quarterly Remedial Investigations, Draft (Tulsa COE, 1989b);	Tulsa COE	1/88 - 6/89	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs	Oklahoma State Department of Health
Tinker AFB Groundwater Assessment Update (Tulsa COE, 1989c); and	Tulsa COE	12/87 - 3/89	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs	Oklahoma State Department of Health
"Sampling Results" (1) Groundwater Report (Tulsa COE, 1988c)	Tulsa COE	3/88, 10/88	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs	Southwest Laboratory of Oklahoma
Final Storm Sewer Investigation For Soldier Creek (NUS, 1989)	NUS Corporation	10/89	Water	VOCs, Metals (Cd, Cr, Cu, Pb, Ni, Zn), Oils and Grease, Chemical Oxygen Demand, Cyanide, Phenols, Phosphorus, Chromium (Hex)	NUS Corporation
Industrial Wastewater Treatment Plant Remedial Investigations Report (Tulsa COE, 1991a)	Tulsa COE	3/88 - 9/90	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs	U.S. Corps of Engineers, Southwest Division Laboratory

NOTES:
(1) "Sampling Results" = No reports were generated.

1.5.1 Sediment Sampling--Radian Corporation 1984

The purpose of the IRP Phase II Confirmation/Quantification Stage 2 investigation performed by the Radian Corporation (Radian, 1985a) was to determine if solvent storage and waste disposal practices resulted in environmental contamination at Tinker AFB. In addition, the investigation presented an estimate of the magnitude and extent of contamination, the identification of environmental consequences of migrating pollutants, and recommendations for additional investigations to identify the magnitude, extent and direction of movement of discovered contaminants. As part of this investigation, twenty-four sediment samples were collected along Crutch Creek (including significant tributaries), Kuhlman Creek, East Soldier Creek, West Soldier Creek, Soldier Creek, a tributary of Elm Creek and two drainage ditches within Tinker AFB on June 20 and July 19, 1984. Seven of these sediment sampling stations were located within East Soldier Creek, West Soldier Creek, Soldier Creek, and two drainage ditches on Tinker AFB and were identified by selected primary data users to be pertinent to the Soldier Creek RI. The locations of six of the seven sediment samples are presented on Figure A-1 of Appendix A, Volume 3 (page A-4). The seventh sampling location is located off-base near Landfill 6. The metals analytical results showed relatively high concentrations in comparison to the other analytical results. Sediment sample analytical results for all analyzed parameters are shown in Appendix A, Volume 3, Table A-2 (page A-3).

Sediment samples were collected using either a hand trowel or a section of 2-inch outside diameter polycarbonate tube. The tube was employed as a "plug" or coring device. Generally, the depth of sampling extended from 6 to 12 inches below the channel bottom as conditions would allow. At several sampling locations, samples were collected as composites obtained from two or more discrete points in the area of the sampling station. Multiple point samples were collected for compositing at sample stations where stream conditions varied significantly with the station reach. Point samples were composited as the station sample to be representative of local stream conditions.

Immediately following the collection and compositing, each sediment sample was placed in a quart glass jar with a Teflon cap liner. Each sample was labeled and packed with ice in an insulated shipping container. Samples were shipped nightly to Radian Analytical Services using an overnight parcel service. All shipments were

made under chain-of-custody control. Once in the laboratory, samples were frozen until analyses were begun.

In general, Radian concluded that sediment analytical results showed no evidence of widespread or elevated levels of industrial contaminants. Radian determined that no other follow-up action was deemed necessary for the area of study.

1.5.2 Sediment and Surface Water Sampling--EPA 1984

The purpose of the report titled "An Evaluation of the Effects of Wastewater Discharges from TAFB on Water Quality of Crutch and Soldier Creeks," (EPA, 1985) was to present data and conclusions resulting from the Oklahoma Water Resources Board (OWRB) investigation of the potential toxics contamination of Crutch and Soldier Creeks. EPA Region VI provided technical assistance to the OWRB by conducting chemical analyses and bioassays on three effluent and five stream samples. Samples were collected by the OWRB and EPA on October 30 through November 1, 1984.

Six sediment sampling locations within Soldier Creek were identified as pertinent to the Soldier Creek RI. The sampling locations and the analytical results for each location are shown on Figure A-2 of Appendix A, Volume 3 (page A-6). The metals (cadmium, chromium, lead, iron); total acid, base/neutral extractables (BNAs); and total volatile organic compounds (VOCs) analytical data for each station is shown on the figure. These data were shown to illustrate the metals concentrations and the possible "hot spots" for BNA and VOC contamination. Additional sampling analytical data for this investigation is shown in Table A-3 of Appendix A, Volume 3 (page A-5).

The precise sampling methodology for collection of the sediment and surface water samples is unknown. The effluent sample from outfall sampling point 1 was collected as a 24 hour composite. The effluent samples from the two other outfall sampling points were collected as single grab samples. Grab samples were collected at each stream sampling station.

EPA concluded that the water quality of Crutch and Soldier Creeks was considered poor due to the concentrations of organic, metal, and other contaminants detected

in the water column. The EPA considered Tinker AFB the primary source of the contamination. Oklahoma Water Quality Criteria for chromium, copper, mercury, and cyanide were exceeded, as were Oklahoma Water Quality Standards for chromium, copper, total dissolved solids (TDS), sulfate and hardness. State sediment quality goals for cadmium and chromium, and the water quality goal for cyanide, were exceeded.

1.5.3 Sediment Sampling--Harry Keith & Sons, Inc. (HKS) 1985

The purpose of the HKS Site Investigation report prepared by HKS (HKS, 1985) was to present analytical results from sediment sampling conducted to determine the magnitude of contamination found in East and West Soldier Creeks.

Sixty-five sediment samples were collected at various locations within East and West Soldier Creeks. Data, including cadmium, chromium, lead, zinc, and total BNA concentrations, for each sampling location along East Soldier Creek are shown on Figure A-3 of Appendix A, Volume 3 (page A-9). The locations of samples collected within West Soldier Creek are unknown at this time. Analytical data from this investigation for both East and West Soldier Creeks are shown in Table A-4 of Appendix A, Volume 3 (page A-7).

Sediment samples were collected using a hand trowel and scoop containing a plastic disposable sleeve that was changed at each sample point and depth. The samples were measured to the proper depth interval (0-2 and 3-5 feet) and placed into a "lab weight" plastic bag with an air tight seal. The sample bag was then placed into another plastic bag to ensure an air tight seal. An additional 400 grams of the same measured sample was placed into a glass jar with Teflon lid. Samples were transported for analysis immediately upon completion of the sample collection for all areas. Analysis was initiated approximately 12 hours after leaving the last sample location. All samples were rechecked for proper identification upon arrival at the laboratory.

HKS observed that East Soldier Creek appeared to have a heavy buildup of a black oily sludge in and adjacent to the stream bed, and all sample sites exuded strong hydrocarbon odors. Many of the sample locations contained an approximately 2-inch-

thick layer of apparently clean sediment with a black oily sludge underneath. The sludge, itself, was not sampled because it was deeper than the sampling zone.

Conclusions presented in the HKS Site Investigation report are described below. Many of the sample sites and the adjacent areas displayed evidence of high water conditions that could have washed away soluble and insoluble compounds which may have been present in the top layer of sediment. Even the normal water level conditions of a stream may carry a portion of the organic and inorganic contaminants downstream by the physical action of stream flow. Therefore, HKS expected extensive downstream effect of the contaminants that were found or had been present in the stream sediment.

1.5.4 Sediment Sampling--HKS 1986

The purpose, sample methodology, specific sampling activities and conclusions of the 1986 HKS investigation (HKS, 1986) are unavailable at this time. The sampling locations, together with the pertinent metals (cadmium, chromium, lead) and VOC concentrations for each location, are shown on Figure A-4 of Appendix A, Volume 3 (page A-11). The sediment analytical results for this investigation are shown in Table A-5 of Appendix A, Volume 3 (page A-10).

1.5.5 IWTP and Sanitary Treatment Plant (STP) Discharge Surface Water Sampling--Tinker AFB 1987

The purpose of this investigation (Tinker AFB, 1987a) was to sample the IWTP and STP water discharge and determine surface water concentrations of specific contaminants of interest. Tinker AFB personnel collected the surface water samples. The sample methodology, specific sampling activities and conclusions of the 1987 surface water analytical results are unavailable. The sampling locations together with the volatile organic analytical results are shown on Figure A-5 of Appendix A, Volume 3 (page A-12).

1.5.6 Sediment and Surface Water Sampling--OSDH 1987

The purpose, sample methodology, specific sampling activities and conclusions of the OSDH investigation (OSDH, 1987) are unavailable. The West Soldier Creek sampling location, together with analytical results for the surface water and sediment samples, are shown on Figure A-6 of Appendix A, Volume 3 (page A-13).

1.5.7 NPDES Surface Water Sampling--Tinker AFB 1987

The purpose of the NPDES surface water investigation done by Tinker AFB (Tinker AFB, 1987b) personnel was to determine surface water concentrations of specific contaminants at prescribed locations downstream of the IWTP effluent discharge. The sample methodology, specific sampling activities and the conclusions of the NPDES water analytical results are unavailable at this time. Sampling locations are shown on Figure A-7 of Appendix A, Volume 3 (page A-15). The surface water analytical results are shown in Table A-6 of Appendix A, Volume 3 (page A-14).

1.5.8 Groundwater Sampling--U.S. Army Corps of Engineers, Tulsa District (Tulsa COE) 1988

Quarterly groundwater sampling and analyses has been conducted as a part of the overall groundwater assessment at Tinker AFB and as a part of the remedial investigation of the Building 3001 Site. The results of the sample analyses have been presented in several reports (Tulsa COE, 1988d; Tulsa COE, 1989b; and Tulsa COE, 1989c). These results are summarized in Table A-7 (page A-16) and Table A-8 (page A-17) of Appendix A, Volume 3 for the wells in the vicinity of West and East Soldier Creek. The well locations are illustrated on Figure A-8 of Appendix A, Volume 3 (page A-20). As a part of the Building 3001 remedial investigation, wells were also sampled in the vicinity of Building 3001 and IWTP in October 1988 to monitor groundwater contamination in that area. These sampling results are summarized in Table A-9 of Appendix A, Volume 3 (page A-19). The well locations are shown on Figure 3-7 (page 3-15). These analytical results have not been summarized on a figure due to the large volume of data that is available. The sampling methodology for both projects is described in the Tinker AFB Sampling and Analysis Quality Assurance/Quality Control Plan for Corps of Engineers Site Investigations (Tulsa COE, 1986).

The Building 3001 Site remedial investigations indicated that the perched aquifer is contaminated with organic solvents, trace metals, and fuel product (Tulsa COE, 1988a). The areas with highest concentrations of contaminants are located beneath Building 3001, the North Tank Area, and the Southwest Tank Area. Trichloroethene (TCE) and chromium are considered the primary contaminants in the perched aquifer since their maximum concentrations were higher than the concentrations of other contaminants and they were consistently detected over a large portion of the

site. Other significant contaminants include 1,2-dichloroethene, tetrachloroethene, acetone, toluene, benzene, and xylene. Other significant inorganic contaminants include lead, nickel, and barium.

The Building 3001 analytical results also indicated that the TCE plume is centered beneath Building 3001 with migration away from the building toward the east, west, and southwest. Analytical results indicated that the areal extent of chromium contamination was similar to the areal extent of TCE contamination. The site hydrogeology is further discussed in Subsection 3.4.2, Site Hydrogeology.

In addition, the Building 3001 analytical results indicated that the contamination in the perched aquifer may be partially due to contaminants that were discharged into storm drains. Records indicated that West Soldier Creek had received discharges from storm drains that contained TCE. Therefore, the TCE contamination may partially be a result of leakage and migration from storm drains and migration from West Soldier Creek.

The supplemental quarterly remedial investigations conducted at the Base have indicated that the areal extent of TCE contamination has not changed significantly from the extent described in the Building 3001 RI report (Tulsa COE, 1989b). The areal extent of chromium contamination appears to have increased slightly. All other contaminants have appeared to remain fairly stable with a general trend for lower concentration of metals (Tulsa COE, 1989b).

1.5.9 Surface Water Sampling--NUS Corporation (NUS) 1989

The purpose of the Storm Sewer Investigation for Soldier Creek performed by NUS Corporation (NUS, 1989) was to identify releases of potential contaminants from the storm sewers emanating from the Building 3001 complex and discharging to East and West Soldier Creeks on Tinker AFB.

There are a total of thirteen outfalls to Soldier Creek tributaries at Tinker AFB. Six of the outfalls are associated with West Soldier Creek and the remaining seven outfalls discharge to East Soldier Creek. The locations of twelve of the outfalls are shown on Figure 1-2 (page 1-4). Outfall N is considered a combination of discharge from Outfalls A, B, C, D, and E, and is not specifically delineated on the figure. The

following summarizes the associated buildings and areas that discharge through each outfall.

<u>Outfall</u>	<u>Building or Area</u>
A	3001
B	Roadway Drainage
C	3001
D	3001
E	3001, 3108
F	3001
G	3001
H	2122, 2210, 3001, 3102, 3105, 3220, 3221, 3234, 3703
I	2122, 2210, 3001, 3102, 3105, 3220, 3221, 3234, 3703
J	Roadway Drainage, Defense Reutilization and Marketing Office Area
L	3001
M	Roadway Drainage
N	Combination of Outfalls A, B, C, D, and E

During the NUS investigation, only eight of the outfalls were observed to have flow (A, D, E, F, G, H, I, and L) (NUS, 1989).

As part of this investigation, seven surface water samples were collected at on-base Building 3001 outfall locations. The locations of these sampling stations are shown on Figure A-9 of Appendix A, Volume 3 (page A-22) together with pertinent volatile organic, oil and grease, and metal analytical results for each location.

Surface water samples were collected over a 24 hour period using an ISCO 2700 continuous sampler. Samples were collected through 3/8-inch diameter polyvinyl chloride tubing and automatically composited in a 3-gallon glass collection vessel. The composite samples were transferred from the collection vessel to individual sample bottles for shipment to the laboratory. Grab samples collected for volatiles and oil and grease analyses were obtained by filling the sample bottles directly from

the storm water overflow at the v-notch. The sample bottles were tagged and sealed prior to shipment. Chain-of-custody forms were completed for all samples and sent with each container for tracking purposes. All sample collection bottles contained the required preservatives before being filled with surface water samples. Surface water analytical results pertinent to the Soldier Creek Site are summarized in Table A-10 of Appendix A, Volume 3 (page A-21).

The storm sewer investigation concluded that the integrity of the storm sewer system discharging to Soldier Creek was adequate and that the main reason for contamination in the creek was because of improper disposal operations (NUS, 1989). The study results indicated that there were four waste sources discharging into Soldier Creek. The four sources consisted of the following:

- (1) Process discharges, including non or limited contact process heating and cooling waters or evaporative cooling waters. This type of discharge constitutes the majority of the discharge volume.
- (2) Low volume accumulative wastes consisting of entrained or condensable oils and water-based wastes. These wastes are generated by the air compressor, vacuum pump, and fume handling systems, and are the primary sources of oil found in the Soldier Creek outfalls.
- (3) Waste materials, including spent cleaning solvents and lubricating oils. These wastes are maintenance related and were manually disposed of into catch basins and roof, floor, or process drains connected to the storm sewer system.
- (4) Cross contamination between waste systems as a result of improper connections.

Several buildings in the vicinity of and including Building 3001 were found to have operational problems that contributed to the contamination of Soldier Creek through the outfalls.

Several recommendations were made by NUS as a result of their storm sewer investigation. Recommendations for improving the storm sewer system were made

for buildings and open areas, outfalls, and non-contact cooling water discharges, which included the following:

- Install high level alarms in all industrial waste lift stations. This has not been done.
- Restructure the management of emulsified waste oil generated at Building 3001. This has not been done.
- At Building 3001, disconnect active floor and sink drains and an inactive sump from the storm water system; reroute the heat treating cleaning station drain to an industrial wastewater line; empty oil filter traps to the IWTP or an oil/water separator; discontinue the discharge of vacuum pump seal oil; and divert non-contact cooling water to the storm sewer system. This has been done.
- Discontinue the discharge of oil and spent solvents to catch basins. This has been done.
- Dredge West Soldier Creek to lower the elevation and rebuild to facilitate drainage and sampling requirements. This has been done.
- Investigate the rerouting of non-contact cooling water and process wastewater from boiler blowdown, softener regenerates, and cooling tower blowdown to the storm sewer system from the IWTP to decrease the hydraulic load at the IWTP and supply flushing water to the storm sewer system to facilitate sampling. This has not been done.

The outfalls on West Soldier Creek vary from partial to total submergence as a result of vegetative growth occurring in the water channel. Because of the vegetative growth, a semi-swamp condition exists that both traps contaminants and raises the water level to the outfalls. As discussed in Subsection 5.3.2 of the NUS report, NUS suggested that the on-base West Soldier Creek area should be reconstructed as an open lined culvert (a type of drainage pipe) incorporating a weir and gate (water flow obstruction) at its discharge end to both measure flows and control the discharge in

case of a spill condition. NUS Corporation also suggested that the individual outfall discharges to this culvert should be designed to accept simple weir plates to provide measurement capabilities for possible future water studies.

East Soldier Creek Outfall L consists of a 30-inch line through which three 4-inch reinforced plastic pipes have been placed. The three pipes were out of service. NUS concluded that all three pipes should be removed from the inside of the outfall line.

1.5.10 IWTP Groundwater Sampling--Tulsa COE 1991

Groundwater sampling and analysis was conducted on monitoring wells in the vicinity of the IWTP between 1988 and 1990 to assess the contamination of groundwater beneath the IWTP. Well locations are shown on Figure 4-14, Volume 2. The perched aquifer, top of regional aquifer zone, and regional aquifer zone wells were sampled at least once during the three-year period. Semi-annual sampling was conducted on the majority of the wells. The samples were analyzed for conductivity, pH, total organic carbon (TOC), volatile and semi-volatile organics, and selected total and dissolved metals (arsenic, barium, cadmium, chromium, lead, mercury, nickel, selenium, silver, and zinc).

The results of the sampling and analysis are presented in the Industrial Wastewater Treatment Plant Remedial Investigations Report, Tinker Air Force Base (Tulsa COE, 1991a), prepared by the Tulsa COE and indicated that the contamination in the top of regional aquifer zone was greater than that in the perched aquifer. Groundwater elevations in all aquifer zones were found to remain fairly constant over the investigation; however, contaminant concentrations in the aquifer zones rapidly increased over the investigation period. Elevated concentrations of several contaminants including chromium, lead, vinyl chloride, 1,1-dichloroethane, 1,1-dichloroethene, trans-1,2-dichloroethene, 1,2-dichloropropane, 1,1,1-trichloroethane, trichloroethene, tetrachloroethene, chlorobenzene, methylene chloride, and 1,2-dichlorobenzene were detected in the groundwater. The analytical results of the IWTP groundwater sampling are presented on Figure 4-14 in Volume 2 of the RI report.

2.0 REMEDIAL INVESTIGATION FIELD ACTIVITIES

This section details the work performed during Phase I and II of the RI field activities, including the sediment investigation, surface water investigation, surface water flow investigation, and groundwater investigation.

2.1 Objectives of the Remedial Investigation

Two separate sets of objectives were established for Phase I and II of the RI, respectively. The primary objective of Phase I was to determine, by medium, the nature and extent of contamination of Soldier Creek and the resulting threat posed by the release or potential release of hazardous substances to the environment.

Based on available site analytical data, medium specific objectives for Phase I of the RI were as follows (BVWST, 1990a):

- Sediment
 - Determine depth of contamination within Soldier Creek stream sediment.
 - Determine downstream extent of contamination within Soldier Creek which may be attributable to Tinker AFB.
 - Determine contaminant concentrations within Soldier Creek sediment.
 - Determine physical and chemical characteristics of sediment for use in the development of potential remedial technologies.
 - Determine sediment particle size fraction(s) which may be a transport mechanism for adsorbed contaminants.
 - Assess correlation of semi-volatile organics vs. metals contamination within Soldier Creek by sample location to attempt to reduce analytical costs in the Phase II field investigation. If a correlation between semi-

volatile organics and metals is determined, only selected metals analyses will be performed on samples collected in the Phase II field investigation.

- Surface Water
 - Determine rate and volume of flow at specific locations along Soldier Creek and major tributaries from Tinker AFB.
 - Assess potential losing and gaining segments of Soldier Creek and major tributaries from Tinker AFB using non-intrusive methods.
 - Determine contaminant concentrations within Soldier Creek water column.
 - Determine off-base inflow points to Soldier Creek and major tributaries from Tinker AFB which may contribute to flow and/or contamination of the stream.
 - Determine physical/chemical characteristics which may affect selection of potential remedial technologies.
- Groundwater
 - Determine water levels in selected existing off-base wells located within the Soldier Creek drainage basin.
 - Determine contaminant concentrations of groundwater collected from selected existing off-base wells.

Based on the Phase I analytical data, the following Phase II objectives were established by medium for the Tinker AFB - Soldier Creek project (BVWST, 1991a):

- Sediment
 - Determine depth to bedrock at all Phase II sampling locations along Soldier Creek.
 - Determine depth of contamination at sampling locations in Soldier Creek that potentially contain chemical concentrations greater than EPA's 10^{-6} (one in one million) health-based risk goal, based on Phase I analytical results.
 - Determine sediment particle size gradation to determine potential transport mechanisms for adsorbed contaminants.
 - Determine physical/chemical characteristics of sediment for use in the development of remedial technologies.
- Surface Water
 - Determine surface water contaminant concentrations at Phase II sediment sampling locations.
 - Determine rate and volume of flow at Phase II sampling locations.
 - Determine water quality characteristics for use in the development of remedial technologies.
- Groundwater
 - Determine the nature and extent of contamination in groundwater, as related to Tinker AFB from Soldier Creek.

- Determine the risk to public health if contamination is migrating from Soldier Creek into the groundwater at Tinker AFB.
- Collect data necessary to perform computer modelling of groundwater associated with the Soldier Creek Site for use of such modelling data in preparing site feasibility studies and remedial designs.

Phase I and Phase II field investigation activities were specifically developed and implemented to obtain data necessary to fulfill each objective described above. In addition, RI field investigation activities served to gather data to support the development and evaluation of remedial alternatives during preparation of the FS Initial Screening of Alternatives report (BVWST, 1993b).

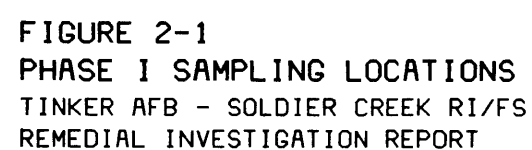
2.2 Phase I - Remedial Investigation

This subsection outlines the work performed during Phase I of the RI field activities including the sediment investigation, surface water investigation, surface water flow investigation, and groundwater investigation.

2.2.1 Sediment Sampling

Forty-one sediment sampling locations were investigated during Phase I of the RI (BVWST, 1990b). Forty-two Phase I sampling locations are illustrated on Figure 2-1 (page 2-5); however, no sediment samples were collected at location W05 because it is underground. Sediment samples were collected at 0-6 and 6-12 inches. A 6-12 inch sediment sample was not obtained at locations E01 and E04 because bedrock was encountered at the 6 inch depth.

Composite sediment samples were collected at each sampling location with each sampling location divided into subsamples across a transect. The samples were collected using the Equal-Width Increment (EWI) method as described in the "National Handbook of Recommended Method For Water Data Acquisition" (USGS, 1980). Each of the composited samples was submitted to the Contract Laboratory Program (CLP) laboratory and analyzed for semi-volatile organics on the Target Compound List (TCL), and metals and cyanide on the Target Analyte List (TAL) using Routine Analytical Services (RAS) detection limits. In addition, Special



Analytical Services (SAS) analyses including Atterberg limits, sediment particle sizes, permeability, and density were performed on samples collected from locations C01, E07, E09, M05, M08, M09, M13, and W06. Phase I sediment analytical results are presented on figures in Volume 2 of the RI report and tables in Volume 3, Appendix B of the RI report. The organic compounds on the TCL, the analytes on the TAL, and the RAS and SAS detection limits for these analyses are presented in tables in Appendix F (Volume 3).

One grab sample, at each depth, was collected first to be analyzed for volatile organics on the TCL using RAS detection limits. The grab was collected from the location, along the transect, most likely to contain volatile organic contamination based on stream morphology and visual inspection.

A background sediment sample was collected from location C01 in the same manner as the sediment matrix samples and analyzed for the same parameters as sediment samples collected from the other forty locations.

Five duplicate sediment samples were collected for quality assurance/quality control purposes. The duplicates were collected from both depths at locations E02, E06, E08, and M08. The fifth duplicate was collected at location W06 for the 0-6 inch depth and at location W08 for the 6-12 inch depth. At W06 bedrock was indicated at the 6-12 inch depth, therefore a duplicate sample was not collected. All duplicates were analyzed for the same chemical and physical parameters as their corresponding samples.

One sediment equipment rinsate blank was prepared and analyzed to determine if the field procedures contributed to any detected sample contamination. The blank was prepared after collecting the sample from location M08 and was analyzed for the same chemical parameters as the sediment samples.

2.2.2 Surface Water Sampling

Forty-one surface water locations corresponding to the same sediment sampling locations were investigated during Phase I of the RI (BVWST, 1990b). Forty-two locations are shown on Figure 2-1 (page 2-5); however, no surface water samples were collected at location W05 because it is underground. Ten of the forty-one

investigated sampling locations including A01, A02, A03, B01, B02, B03, M02, M03, W01, and W09 did not contain water and, therefore, no surface water samples were obtained.

At each of the thirty-one surface water sampling locations, one grab and one composite sample were collected from the mid-water column depth. The discrete grab surface water sample was collected first at the point along the transect most likely to contain volatile organic contamination based on stream morphology and visual observation. The criteria for selection of the grab sample location along the transect included low velocity stream areas, stained and discolored areas, and deep stream areas. The grab was analyzed for volatile organics on the TCL.

At each location, surface water samples were taken across the transect on intervals determined by the EWI method and composited into one sample. Each composited surface water sample was submitted to the CLP laboratory and analyzed for semi-volatile organics on the TCL, and metals and cyanide on the TAL. In addition, SAS analyses were performed on samples from eight of the sampling locations (C01, E07, E09, M05, M08, M09, M13, W06), including alkalinity, hardness, chemical oxygen demand (COD), total suspended solids (TSS), 5-day biochemical oxygen demand (BOD₅), TOC, oil and grease, and nitrates. Phase I surface water analytical results are presented on figures in Volume 2 of the RI report and tables in Appendix B (Volume 3). The detection limits for these analytes are presented in tables in Appendix F (Volume 3).

During composite sampling procedures additional composited surface water was collected in a separate stainless steel pan and tested for temperature, dissolved oxygen (DO), specific conductivity, and pH. The surface water collected for this purpose was immediately returned to the stream upon completion of sampling activities at each location.

A background surface water sample was collected from location C01 in the same manner and analyzed for the same parameters as surface water samples collected from the other thirty locations.

Five duplicate surface water samples were collected for quality assurance/quality control purposes. The duplicates were collected at locations E02, E06, E08, M08, and W08 and were analyzed for the same chemical and water quality parameters as their corresponding samples.

One surface water equipment rinsate blank was prepared and analyzed to determine if the field procedures contributed to any detected sample contamination. The blank was prepared for location M08 using the sample method used for the surface water samples and was analyzed for the same chemical and water quality parameters.

Three surface water trip blanks were prepared by the CLP laboratory, shipped to the Soldier Creek Site, and shipped back to the CLP laboratory in the coolers containing samples for volatile organic analyses. The purpose of the trip blanks was to determine if any contamination in the samples was caused by transportation of the samples.

2.2.3 Surface Water Flow Investigation

Surface water velocity and stream water depth were assessed in the field at all surface water sampling locations containing appreciable flows, and at stations located every 500 feet along Soldier Creek (including those tributaries that emanate from Tinker AFB) from its headwaters located just north of Landfill 6 to East Reno Avenue (BVWST, 1990b). These measurements were made in order to determine the rate and volume of flow along each segment of the stream. Surface water velocity was not measured at locations that did not contain surface water or had velocities below detection. A summary of these measurements is included in Table B-124 (page B-141) of Appendix B (Volume 3).

2.2.4 Groundwater Sampling

Groundwater samples were collected at eight existing off-base private wells located within the Soldier Creek drainage system as shown on Figure 2-1 (page 2-5) (BVWST, 1990b). Well construction and completion information is not available for these wells, including information pertaining to the producing aquifers, the depth of production, the age of the wells, and the screened interval for the eight existing wells. Groundwater temperature, specific conductivity, and pH measurements were taken at each well; these results are shown in Table B-129, page B-147 (Appendix B,

Volume 3). Groundwater samples from each of the eight wells were analyzed for volatile and semi-volatile organic compounds on the TCL and metals and cyanide on the TAL. SAS detection limits were used to analyze the samples. In addition to collecting unfiltered groundwater samples from four wells (G02, G03, G07, G08), groundwater samples were also collected from these wells and filtered for metals analysis to determine the total metals adsorbed onto soil particles and the fraction in the dissolved phase. The Phase I groundwater analytical results are presented on figures in Volume 2 of the RI report and tables in Appendix B (Volume 3). The results for the filtered and unfiltered groundwater samples are presented in Table B-128 (page B-146) of Appendix B (Volume 3). The detection limits for these analyses are presented in tables in Appendix F (Volume 3).

Background groundwater concentrations for the area in the vicinity of Tinker AFB were obtained from the Off-Base Groundwater Investigations Northeast of the Base report (Tulsa COE, 1991b). Monitoring well TOB-21B was selected as a background monitoring well for the perched aquifer and monitoring wells TOB-14A and B, TOB-15A and C, and TOB-16A and C were selected as background monitoring wells for the top of regional and regional aquifer zones. These wells were selected because historical levels of groundwater contamination detected in the wells was low and, in the case of TOB-21B, the available data indicated that this well was located at a side gradient location in the perched aquifer.

One duplicate groundwater sample was taken at well G08 for quality assurance/quality control purposes. The duplicate sample was collected using the same procedures and analyzed for the same chemical parameters as the groundwater samples.

One groundwater equipment rinsate blank was collected at well G07 and analyzed to determine if the field procedures contributed to any detected sample contamination. The blank sample was prepared using the same procedure and analyzed for the same chemical parameters as the groundwater samples.

Two groundwater trip blanks were analyzed for volatile organics to determine if any contamination in the samples was caused by transportation of samples. The trip blanks were prepared by the CLP laboratory and shipped to the appropriate

sampling locations. A trip blank was sent with each shipment of groundwater samples.

2.3 Phase II - Remedial Investigation

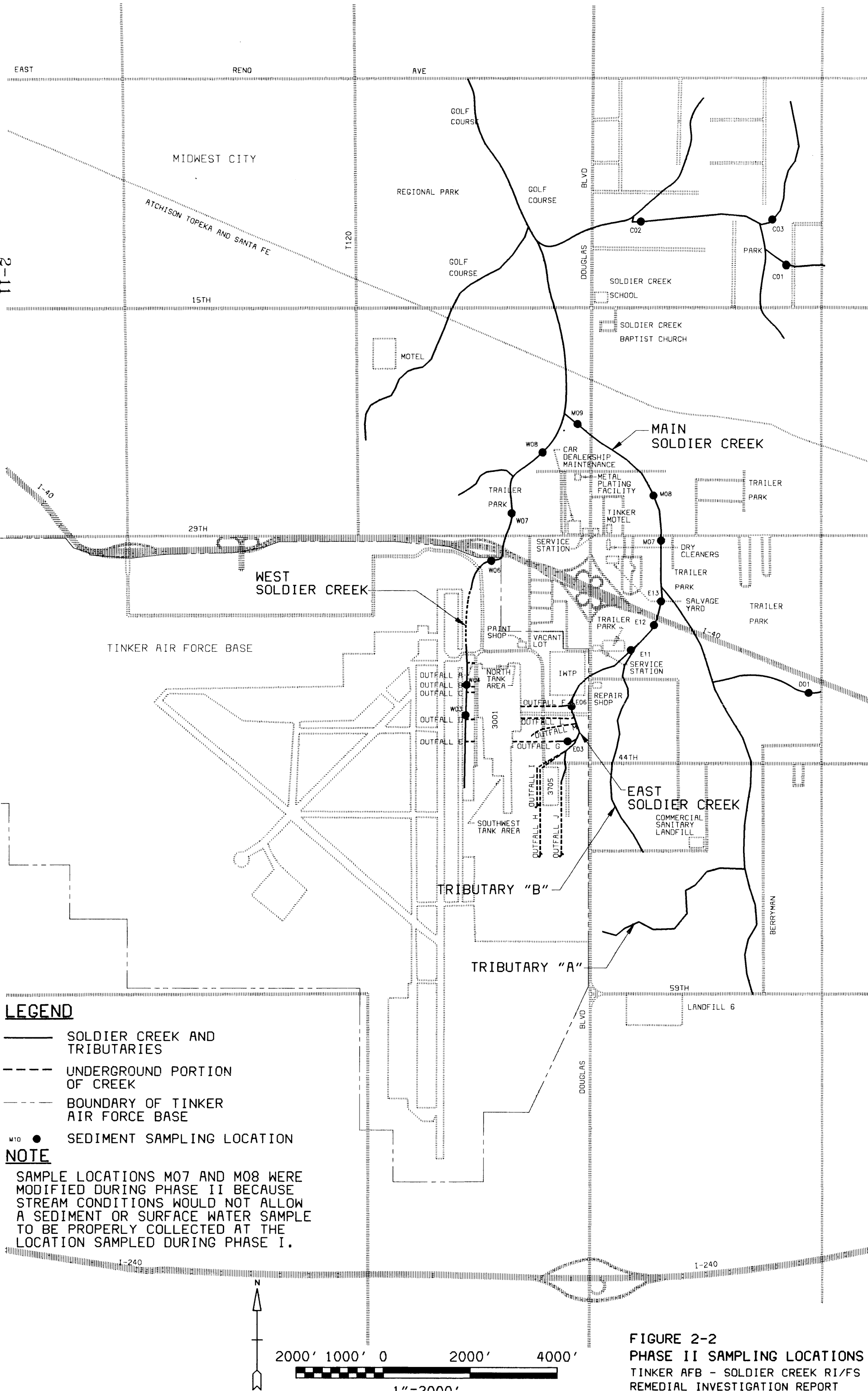
This section outlines the work performed during Phase II of the RI field activities including sediment investigation, surface water investigation, surface water flow investigation, and groundwater investigation.

2.3.1 Sediment Sampling

Seventeen sediment sampling locations, shown on Figure 2-2 (page 2-11), were investigated during Phase II of the RI (BVWST, 1991a). These sampling locations were chosen based on the analytical results of Phase I and the Phase II objectives listed in Subsection 2.1.

At each sampling location, one discrete grab sediment sample was collected at each depth and analyzed for volatile organics on the TCL. This grab sediment sample was collected at the subsample location that was judged to be most likely to contain volatile organic contamination based on stream morphology and visual observations. For example, if the creek contained a meander at a sampling location, the grab sediment sample was collected on the outside portion of the creek meander or in visually discolored sediment.

Composite sediment samples across a transect were collected at five depths (0-1, 1-2, 2-3, 3-4, 4-5 feet) and analyzed for metals (lead, chromium, antimony, cadmium) and cyanide using SAS detection limits. One sample from each subsample depth (0-1, 1-2, 2-3, 3-4, and 4-5 feet) was collected and composited at 5 locations and analyzed using the Toxicity Characteristic Leaching Procedure (TCLP) analysis. In addition, one sample from one subsample depth was collected and composited at 12 sample locations and analyzed using the TCLP. At the on-base locations (E03, E06, W03, W04), each of the 5 subsamples were collected and analyzed for semi-volatile organics on the TCL. In addition, SAS analyses including Atterberg limits, grain particle size distribution, total organic carbon and density were performed on all collected sediment samples. Phase II sediment analytical results are presented on



figures in Volume 2 of the RI report and tables in Appendix B (Volume 3). The detection limits for these analyses are presented in tables in Appendix F (Volume 3).

Composite sediment samples were collected at each sampling location with each sampling location divided into subsamples across the creek transect. All sediment samples and subsamples were taken with a standard two-foot split spoon. The number of subsamples used to form a composite was dependent upon the width of the creek at each sample location. The same number of subsamples at each specific location were collected as were collected in the Phase I field investigation. A minimum of three subsamples were collected, spaced at a distance of 5 feet apart. At sample locations having a stream width less than 10 feet, subsamples were taken at the creek banks and in the middle of the creek. The samples were collected using the EWI method as described in the "National Handbook of Recommended Method For Water Data Acquisition" (USGS, 1980).

Four sediment background samples were collected from locations C01 (previously sampled during the Phase I RI), C02, C03, and D01. The precise locations of these off-base background samples were determined during the field investigation. These background sediment samples were collected in the same manner and analyzed for the same parameters as sediment samples except no acid, base/neutral extractable analyses were performed.

A total of nine duplicate sediment samples were collected at the 0-1 foot interval from locations C02, M08, M07, E13, E12, E06, and W06. An additional duplicate sample was collected at E06 at the 1-2 foot interval. A duplicate was also collected at M08 from the 3-4 foot interval. The duplicate sample analytical results were used for quality assurance/quality control purposes. These duplicate samples were analyzed for the same chemical parameters as the sediment samples.

Two sediment equipment rinsate blanks were prepared and analyzed to determine if the field procedures contributed to any detected sample contamination. One rinsate blank was collected using the sediment sampling equipment and procedures. The second rinsate sample was collected by pouring High Purity Liquid Chromatography water through the split spoon and into a previously decontaminated stainless steel bowl and transferred to the sample bottles.

2.3.2 Surface Water Sampling

Thirty-five surface water samples, including quality control and background samples, were collected at the same 17 sampling locations as the sediment samples (BVWST, 1991a). A composite surface water sample was collected at each location from surface water subsamples collected across the stream transect at the mid-water column depth. All composite surface water samples were analyzed for the metals lead, chromium, antimony, and cadmium. In addition, alkalinity, hardness, COD, TSS, BOD₅, TOC, and nitrates analyses were performed on each sample using SAS procedures. Phase II surface water analytical results are presented in Tables B-73 through B-125, pages B-90 through B-143, Appendix B, Volume 2 of the RI report. The detection limits for these analyses are presented in tables in Appendix F (Volume 3).

At each sampling location, a discrete grab surface water sample was collected first and analyzed for volatile organics on the TCL. This grab surface water sample was located at the subsample location which was determined in the field to be most likely to contain volatile organic contamination based on stream morphology and visual observations. The criteria for selection of the grab sample location along the transect included low velocity stream areas, stained and discolored areas, and deep stream areas. Temperature, specific conductivity, DO, and pH measurements were taken in the field at each surface water sample location after the collection of surface water samples.

Four surface water background samples were collected off-base at the same locations as the sediment background samples. The background surface water samples were collected in the same manner and analyzed for the same parameters as surface water samples discussed previously.

Two duplicate surface water samples were collected at locations C02 and M08. The exact location of these duplicate samples was determined in the field. The duplicate samples were used for quality assurance/quality control purposes. These duplicate samples were analyzed for the same chemical parameters as the surface water samples.

Two surface water equipment rinsate blanks were prepared using the same sampling method used to collect the surface water samples. These blanks were collected and analyzed to determine if the field procedures contributed to any detected sample contamination. These blank samples were analyzed for the same chemical analyses as the matrix surface water samples.

Six water trip blanks were prepared by the CLP laboratory, shipped to the Soldier Creek Site, and shipped back to the CLP laboratory with each shipment of surface water samples. The purpose of the trip blanks was to determine if any contamination in the samples was caused by transportation of the samples.

2.3.3 Surface Water Flow Investigation

Soldier Creek surface water velocity was determined in the field at each Phase II surface water sampling location (BVWST, 1991a). Surface water velocity was not measured at locations that had velocities below detection. These measurements allowed computation of rates and volumes of flow which will allow for qualitative determinations of losing and gaining portions of Soldier Creek. A summary of these measurements is shown in Table B-125 (page B-143) of Appendix B (Volume 3).

2.3.4 Groundwater Sampling

The 21 groundwater monitoring well clusters used in this report are shown on Figure 4-13 (Volume 2) of the RI report. These well clusters are part of the groundwater monitoring program used in the Off-Base Groundwater Investigations Northeast of the Base (Tulsa COE, 1991b) and were selected because they are situated in the Soldier Creek drainage basin. The boring logs are contained in Appendix E, Volume 3. Monitoring well construction logs and groundwater sampling procedures are located in Appendix G, Volume 3. The groundwater monitoring well sampling was completed to aid in determining the extent of off-base groundwater contamination potentially attributable to Tinker AFB from the Soldier Creek Site.

Each well cluster has a well installed in the perched aquifer where present, the top of regional aquifer zone, and in the regional aquifer zone. Groundwater level, geophysical logs, and groundwater samples were collected at the newly installed groundwater monitoring well locations. Groundwater samples were analyzed for metals, volatile organics, semi-volatile organics, pH, and conductivity using SAS

detection limits. The detection limits for these analyses are presented in tables in Appendix F (Volume 3).

For quality assurance/quality control purposes, one groundwater duplicate sample was collected for every ten groundwater samples in triplicate. One sample from the triplicate was sent to the Corps of Engineers' Southwest Division Laboratory as an audit sample for the contract laboratory, and the other two samples of the triplicate were sent to the analytical laboratory as a matrix sample and a quality control sample. Duplicates were collected and tested for the same parameters as in the groundwater samples.

In addition to the duplicate groundwater samples, equipment blanks for water samples were collected. These samples consisted of American Society for Testing and Materials (ASTM) Type II reagent water poured over or through non-dedicated sampling equipment such as bailers to verify the sampling techniques. The equipment blanks were collected and analyzed for the same chemical parameters as the groundwater samples. Equipment blanks were collected at a frequency of one blank for every 20 matrix samples.

A trip blank was shipped with each shipping container containing groundwater samples to be analyzed for volatile organics. This trip blank was analyzed for volatile organics to aid in determining if cross-contamination occurred during shipping. The trip blank consisted of ASTM Type II reagent water sealed into a sample vial in the field laboratory.

3.0 PHYSICAL CHARACTERISTICS OF THE SOLDIER CREEK SITE

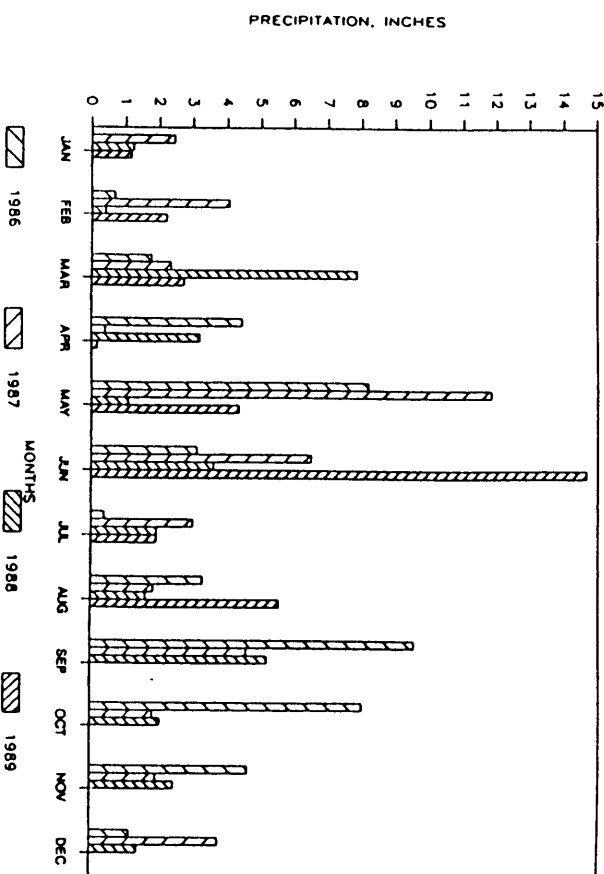
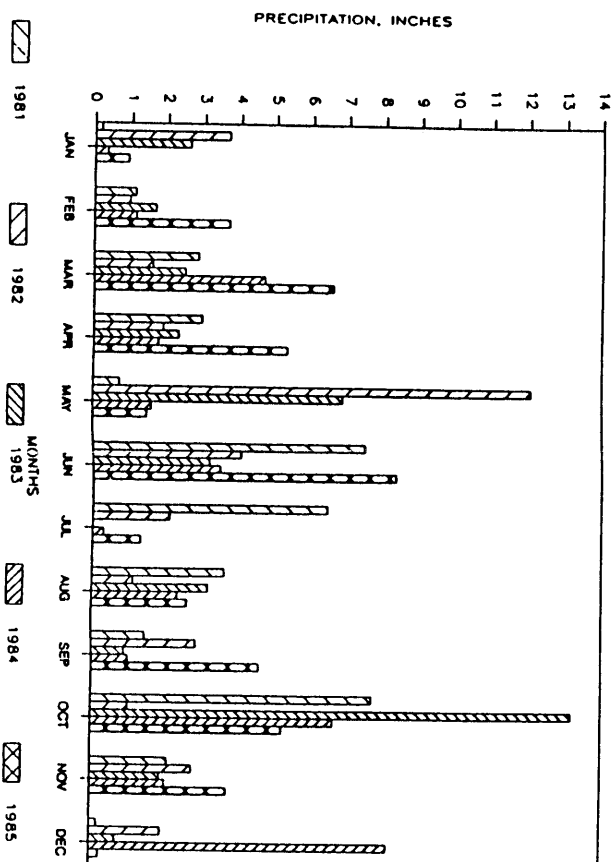
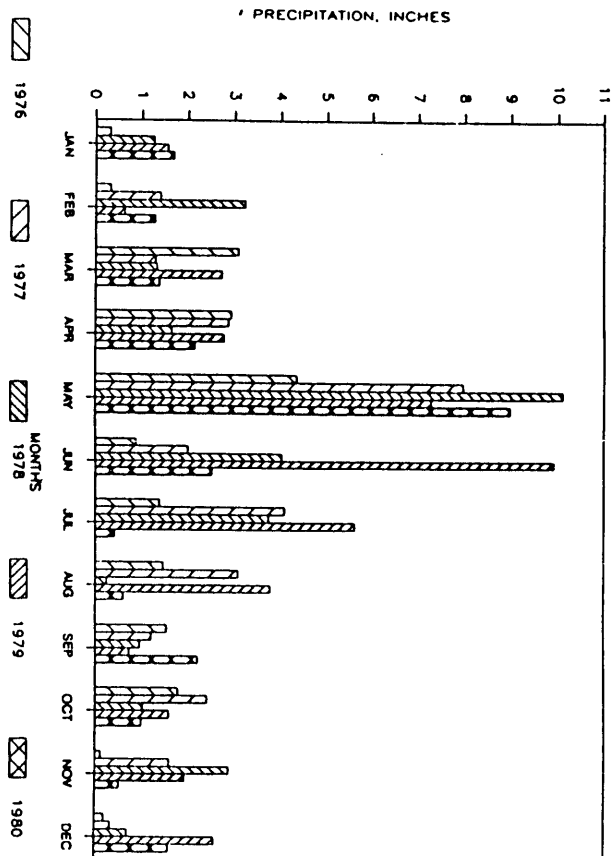
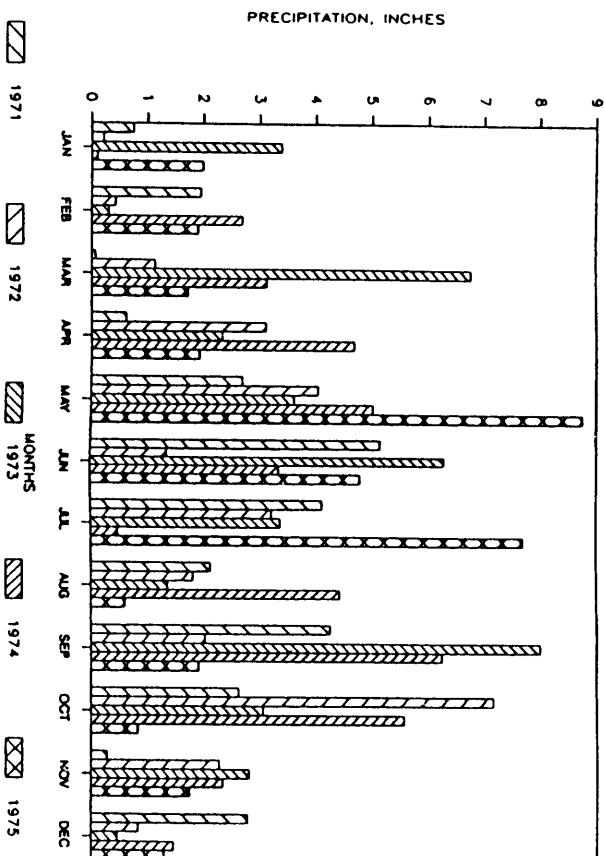
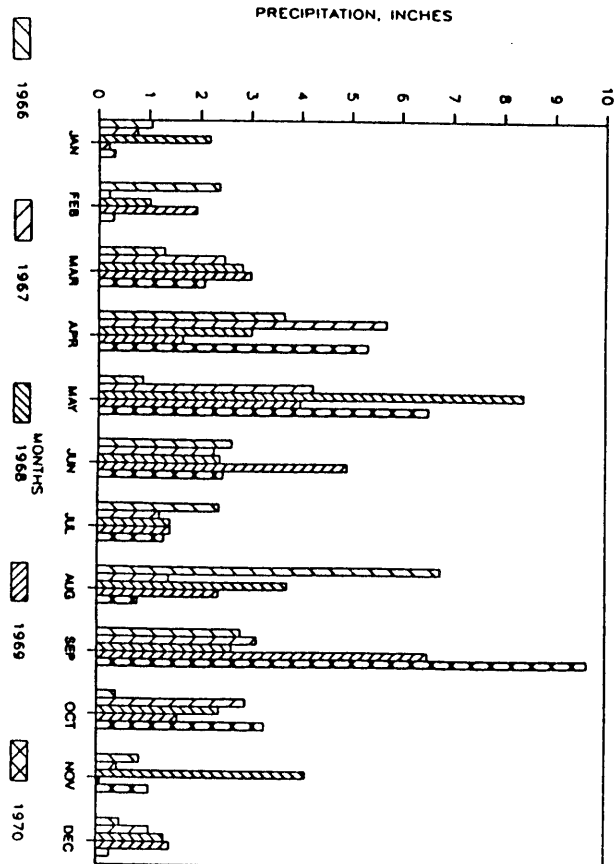
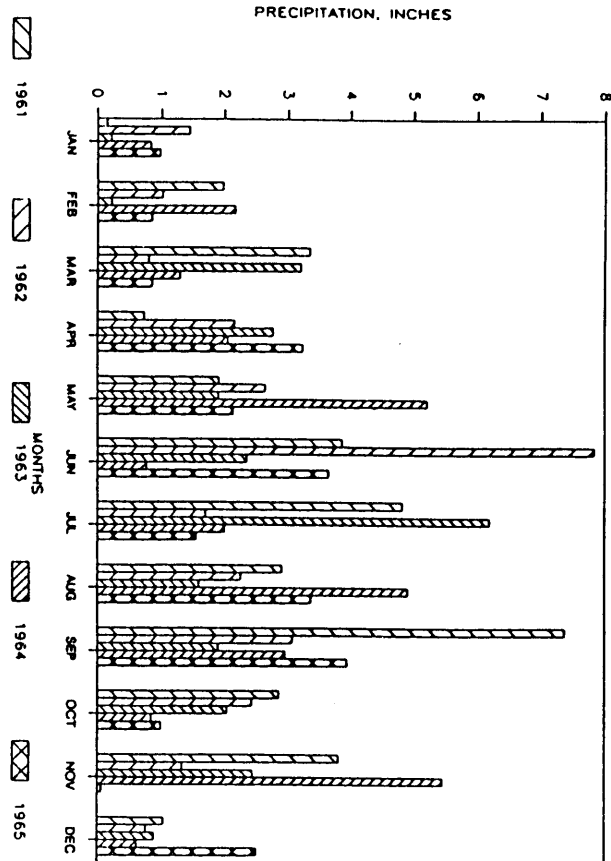
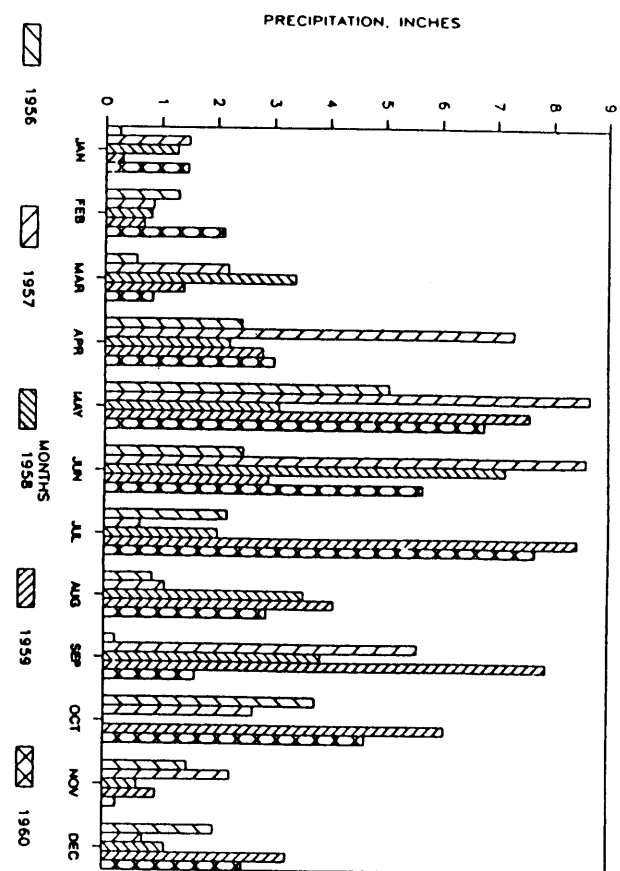
This section presents the physical characteristics of the Soldier Creek Site including the climatology, topography and surface drainage, and regional and site geology and hydrogeology for the Soldier Creek Site. Surrounding land use and ecological conditions are also described in this section.

3.1 Climatology

Meteorological information for the Soldier Creek Site was compiled from weather data for the years 1956 through 1989 recorded at the Will Rogers World Airport (National Climatic Data Center, 1989, 1988, and 1985). Will Rogers World Airport is located approximately 10 miles to the west of Tinker AFB as shown on Figure 1-1 (page 1-3). The meteorological information from Will Rogers World Airport was supplemented by weather data recorded at Tinker AFB for the years 1981 through 1990 (Tinker AFB, 1981-1990).

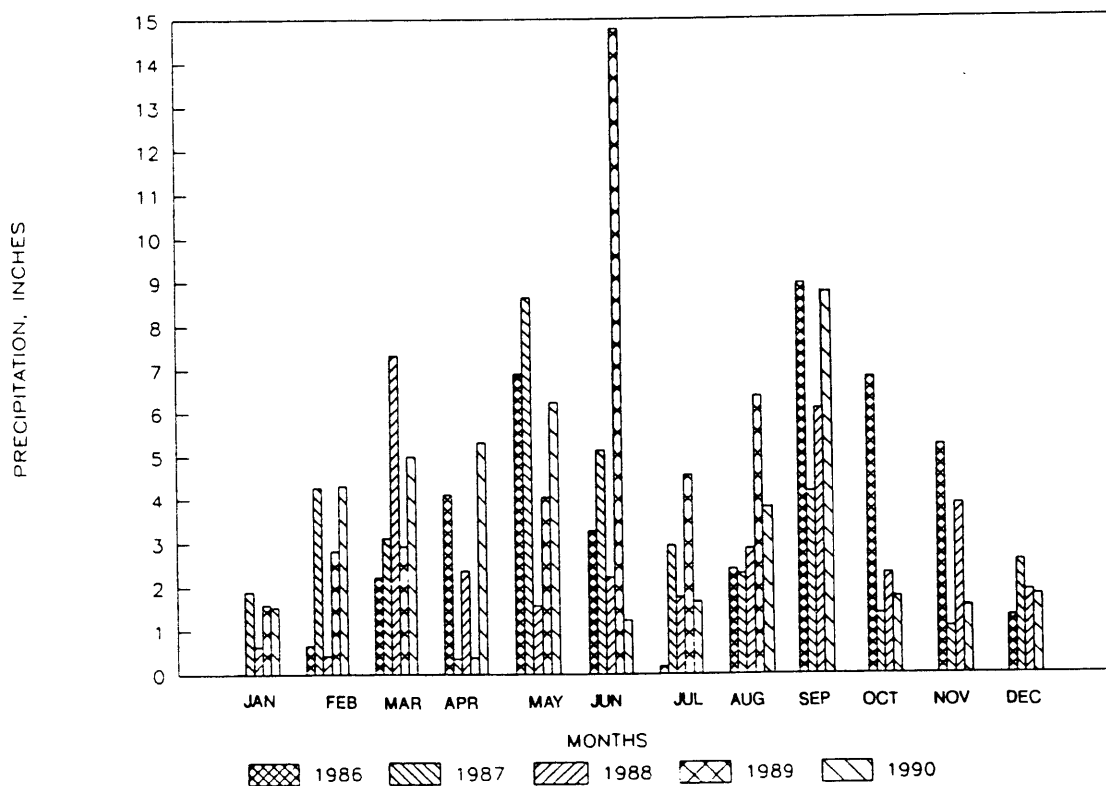
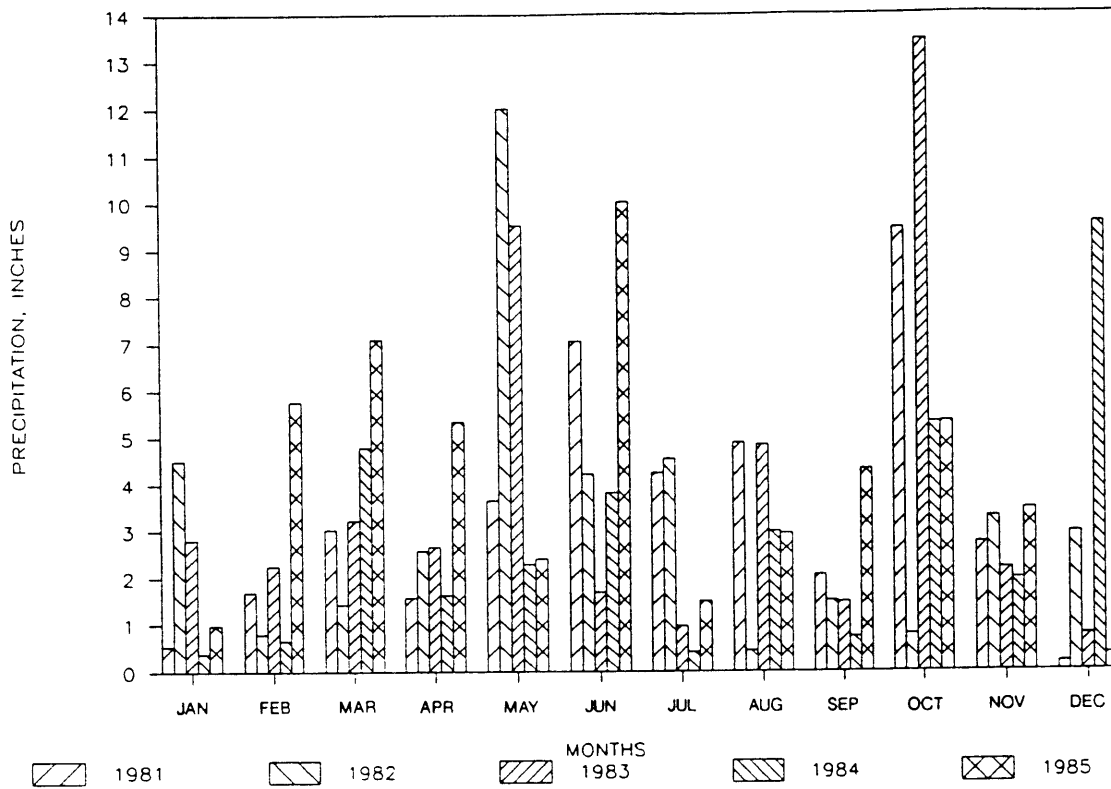
The mean annual precipitation for Will Rogers World Airport is 32.15 inches based on data from 1981 through 1990. From 1981 to 1988, the average annual precipitation was 39.20 inches for Will Rogers World Airport and 40.33 inches for Tinker AFB which are slightly greater than the long-term annual mean. The difference in reported annual precipitation for the two airports ranged from 2.5 to 17.8 percent over the eight year period, with Tinker AFB typically reporting higher annual precipitation than Will Rogers World Airport.

Figures 3-1 (page 3-2) and 3-2 (page 3-3) illustrate the monthly variation in precipitation for Will Rogers World Airport and Tinker AFB. According to data for Will Rogers World Airport, the highest average monthly precipitation is 5.21 inches and occurs in May. June, September, and April also have high average precipitation of 4.00, 3.23, and 3.18 inches, respectively. Months with lowest average monthly precipitation are January, February, and December with averages of 1.26, 1.27, and 1.49 inches, respectively. The average monthly precipitation for the remaining months of the year is between 2 to 3 inches.



REFERENCE: NATIONAL CLIMATIC DATA
CENTER, 1989, 1988, AND 1985

FIGURE 3-1
MONTHLY PRECIPITATION
WILL ROGERS WORLD AIRPORT
TINKER AFB - SOLDIER CREEK R/F/S
REMEDIAL INVESTIGATION REPORT



REFERENCE: TINKER AFB, 1981-1990

FIGURE 3-2
MONTHLY PRECIPITATION
TINKER AFB
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

Snowfall typically occurs in the months of November through March with only trace amounts falling in October and April. The average yearly snowfall is 9.4 inches with the majority falling in January (average 3.1 inches) and February (average 2.6 inches).

The average annual temperature recorded at Will Rogers World Airport is 60.1 degrees fahrenheit (F). The warmest months of the year are June and July with mean temperatures of 81.6 F and 81.3 F, respectively. The coldest months are January and December with mean temperatures of 36.9 F and 39.8 F, respectively. The normal daily maximum temperatures are highest in July (93.5 F) and August (92.8 F) and lowest in January (25.2 F), February (29.4 F), and December (29.1 F). The mean number of days per month with temperatures over 90 F is greater in July and August when there is an average of 23 days over 90 F. January and December have an average of over 20 days each with minimum temperatures below 32 F. The highest recorded temperature is 110 F and occurred in August 1980. The lowest recorded temperature is -4 F and occurred in January 1988.

The annual mean wind speed is 12.4 miles per hour (mph) with the predominant direction from the south-southeast. During January and February the prevailing wind direction is from the north. During the months of November and December, the prevailing direction is from the south. Highest mean monthly wind speeds occur in March and April with magnitudes of 14.6 and 14.4 mph, respectively. The prevailing wind direction during these months is from the south-southeast.

3.2 Topography and Surface Drainage

This subsection describes the regional and site-specific topography and surface drainage conditions that exist at the Soldier Creek Site.

3.2.1 Regional Topography and Surface Drainage

Tinker AFB is located in a regional area characterized by nearly level to gently rolling hills, broad flat plains and well-entrenched main streams. Local relief is primarily the result of surface dissection by erosional activity and stream channel development. At Tinker AFB, ground elevations range from 1,210 feet (on the northwest portion of the Base) to about 1,320 feet mean sea level (at the southeast corner of the Base) (Radian, 1985b).

The principal surface water drainage ways for Tinker AFB are Crutchko, Kuhlman, and Soldier Creeks. The extreme southern part of the Base is drained by Elm Creek (Figure 3-3, page 3-6), an intermittent stream, which flows to the south and discharges into Stanley Draper Lake. Most of the Base is drained by Crutchko Creek and its tributary, Kuhlman Creek. Crutchko Creek flows to the north and northwest and discharges into the North Canadian River. Soldier Creek, the focus of this study, is located mainly to the east of Tinker AFB. Soldier Creek flows to the north and discharges into Crutchko Creek approximately three miles upstream of the confluence of Crutchko Creek and the North Canadian River. Two tributaries of Soldier Creek receive surface water drainage from the eastern portion of Tinker AFB. East Soldier Creek, located on Tinker AFB, collects runoff from roads, parking areas and buildings on the eastern portion of the Base, as well as discharge from several storm drains from the Building 3001 area. NPDES permitted discharges from the industrial wastewater and sewage treatment plants are released into East Soldier Creek. Approximately 800,000 gallons per day are discharged from the IWTP. West Soldier Creek, also located on Tinker AFB, collects runoff from the runway system and receives storm drain discharges from Building 3001. Figure 3-3 (page 3-6) shows the location of Soldier Creek and its approximate drainage boundaries determined from the United States Geological Survey (USGS) topographic maps for the area (USGS, 1975 and 1986).

Based on a stream water quality investigation by EPA Region VI, it was concluded that the water quality of Crutchko and Soldier Creeks is poor due to the relatively large number of organics, metals, and other contaminants detected (EPA, 1985). The surface water analytical results of the Soldier Creek Site remedial investigation are presented in Subsection 4.2 of this report.

3.2.2 Site Topography and Surface Drainage

During Phase I and II of the RI, the topography and surface drainage were observed and recorded in project logbooks. The topographic characteristics observed during the RI ranged from open agricultural fields in the south and east of Tinker AFB to light industrial areas to the immediate north and west of Tinker AFB.

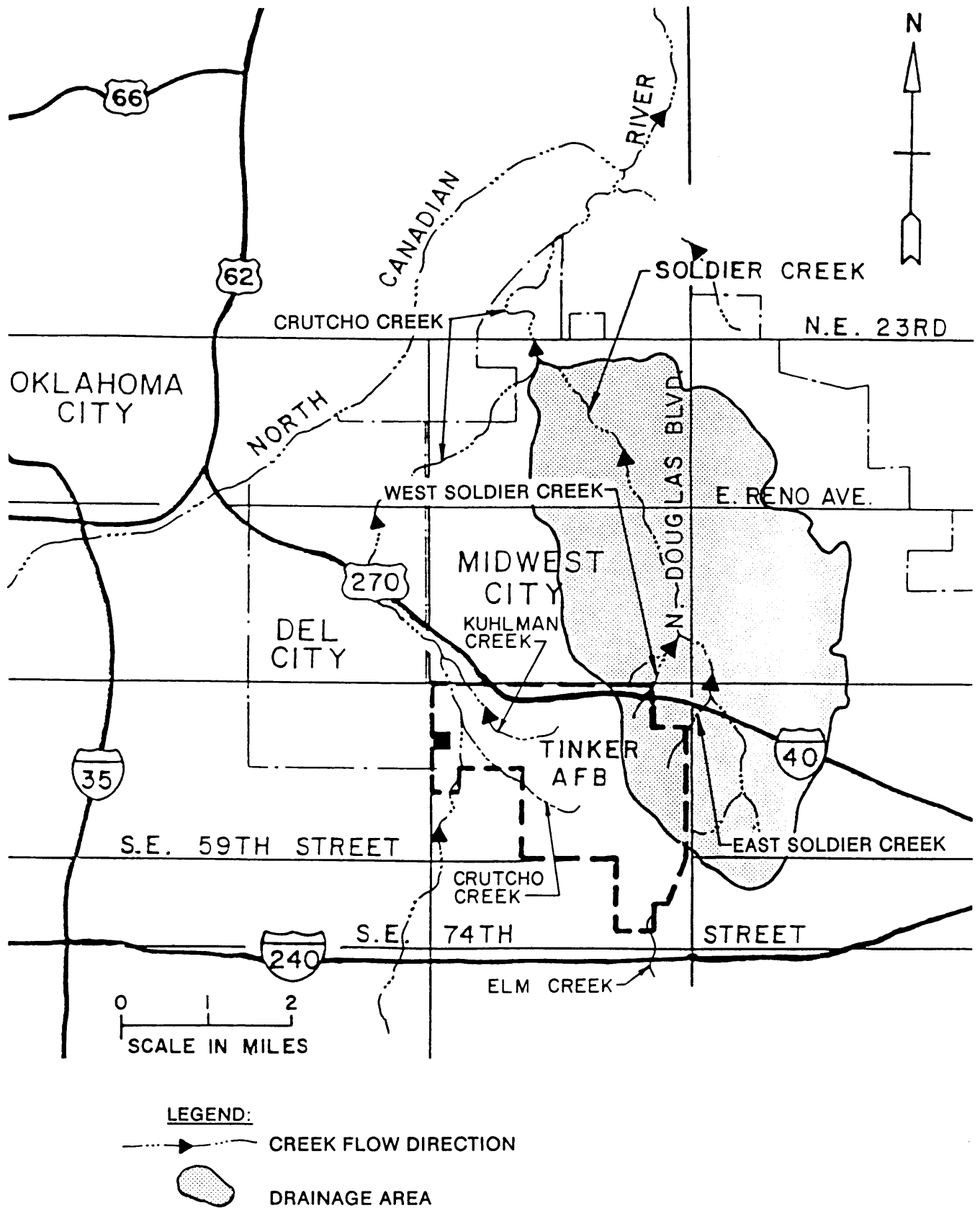


FIGURE 3-3
 APPROXIMATE DRAINAGE
 BOUNDARY - SOLDIER CREEK
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

The four background sample locations (C01, C02, C03, and D01) were collected on off-base tributaries of Main Soldier Creek (Figure 2-2, page 2-11). These background samples were collected in residential areas that contained heavy brush and trees along the banks of the creek. These background locations had broad flat access to Soldier Creek from the surrounding land with less than a 10 foot drop in elevation.

The sampling locations along Main Soldier Creek (M07, M08, and M09) consisted of rural areas surrounded by trees and agricultural fields. These locations had steep elevation drops to Soldier Creek from the surrounding land. The steep drop in elevation required that these original sampling locations be changed to locations accessible by the heavy equipment used during sampling.

The off-base sampling locations along East Soldier Creek (E11, E12, and E13), were located in residential trailer park areas that were heavily wooded with steep elevation drops to Soldier Creek from the surrounding land. Sampling locations E11 and E12 contained trash including tires, wood, concrete, and appliances within the stream bed. A dark organic substance with a distinct oil or diesel fuel odor was encountered within the sediment at E11 and E12. Locations E11 and E12 are near a septic tank outfall from the trailer park.

The on-base sample locations along East Soldier Creek (E03 and E06) were surrounded by landscaped grass areas with trees, and wooded areas. Both locations had a thin layer of oil-containing material on the sediment. There was a gradual elevation drop to Soldier Creek from the surrounding land.

The off-base sample locations along West Soldier Creek including (W06 and W07) were located in wooded areas near Interstate 40. Both locations had paper trash within the stream bed and had a gradual elevation drop to West Soldier Creek from the surrounding land.

The on-base sample locations along West Soldier Creek (W03 and W04) were located adjacent to the Tinker AFB runway west of Building 3001. Both locations have broad elevation drops to West Soldier Creek from the surrounding land.

3.3 Regional and Site Geology

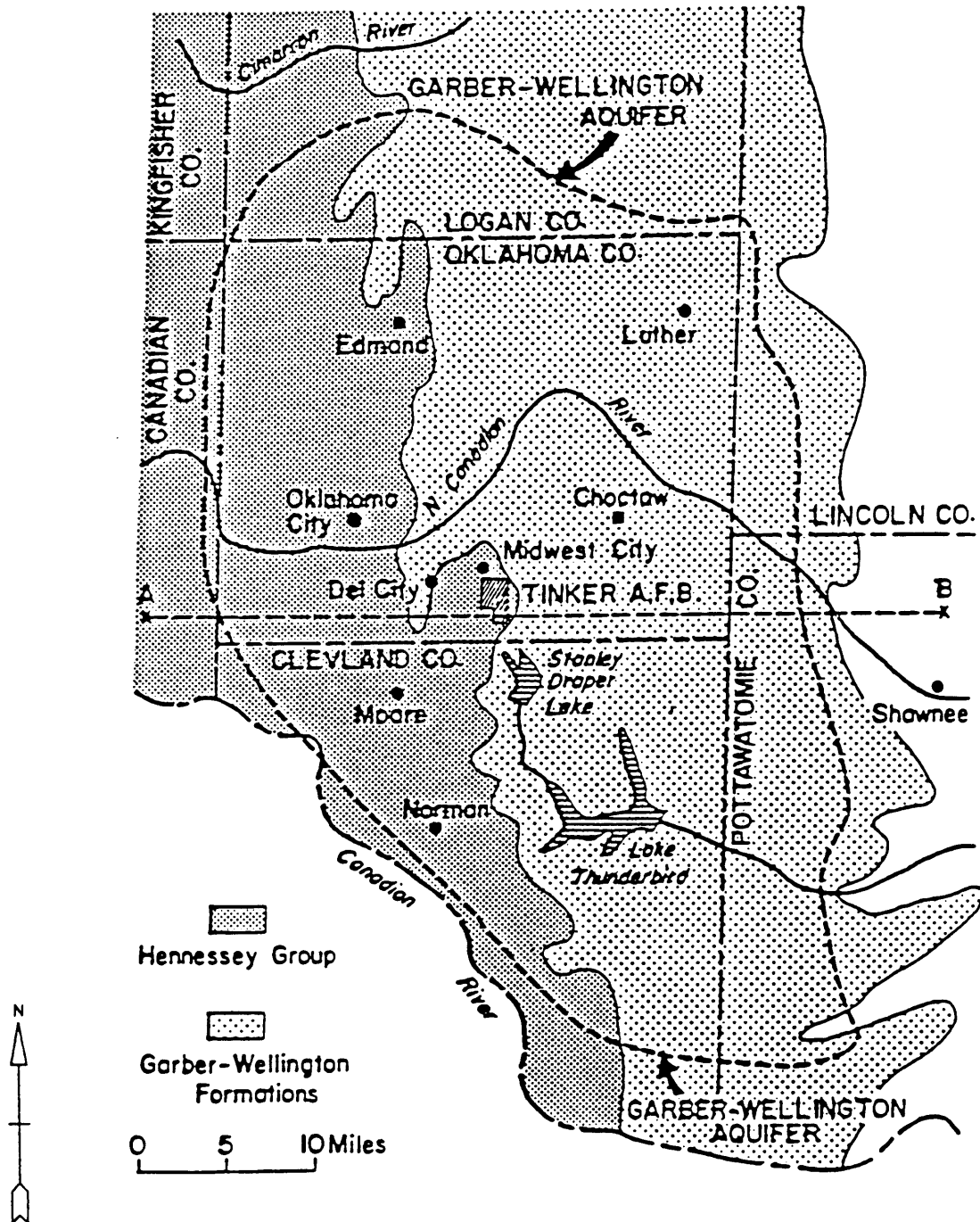
This section describes the regional and site-specific geologic conditions that exist at the Soldier Creek Site.

3.3.1 Regional Geology

Tinker AFB is located within the Osage Plains section of the Central Lowland physiographic province of the Interior Plains division of the United States (Fenneman, 1946). A generalized geologic map of the study area is shown on Figure 3-4 (page 3-9). A discussion of soils and geology within the Tinker AFB region is presented in this section.

The four major surface soil associations present in the area surrounding the Soldier Creek Site are the Darnell-Stephenville, Dougherty-Norge-Teller, Renfrow-Vernon-Bethany, and Dale-Canadian-Port. All these soils are predominantly fine-grained residual and alluvial deposits. Residual soil associations, the Darnell-Stephenville, Dougherty-Norge-Teller, and Renfrow-Vernon-Bethany, are the product of in-place weathering of underlying bedrock (USDA, 1969). The Darnell-Stephenville association soils are described as sandy loam, sandy clay loam, and soft sandstone. Permeability of these soils varies from 1.4×10^{-3} to 4.4×10^{-3} centimeters per second (cm/s). The Dougherty-Norge-Teller association soils are described as loamy sand, sandy clay loam, clay loam, and silty clay loam. Permeability of these soils ranges from 4.2×10^{-5} to 1.4×10^{-3} cm/s. The Renfrow-Vernon-Bethany association soils are comprised of silt and clay loam, and weathered shale. Permeability of these soils varies from less than 4.2×10^{-5} to 1.4×10^{-3} cm/s. The alluvial soil association, Dale-Canadian-Port, are stream deposited silts and sands, whose occurrence is generally restricted to the floodplains of area streams. These alluvial deposits consist of fine sandy loam, silty clay loam, loam and clay loam, and have a permeability range of 3.5×10^{-5} to 4.5×10^{-3} cm/s.

Soils of the Renfrow-Vernon-Bethany association exhibit slow infiltration rates, slow to very slow water transmission rates, and higher runoff potential. The engineering classification [Unified Soil Classification System (USCS)] of soils in this association include inorganic clay and silt with slight to medium plasticity (CL, ML) and inorganic clay and silt with high plasticity (CH, MH).



SOURCE: TULSA COE, 1991.

FIGURE 3-4
GENERALIZED GEOLOGIC MAP OF
THE STUDY AREA
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

Soils of the Darnell-Stephenville, Dougherty-Norge-Teller, and the Dale-Canadian-Port associations are characterized by moderate to slow infiltration rates, moderate to slow water transmission rates, and moderate to high runoff potential. The engineering classification of soils in the Dougherty-Norge-Teller association include silty and clayey sand (SM, SC) and inorganic clay and silt with slight to medium plasticity (CL, ML). Darnell-Stephenville soils are classified as silty and clayey sand (SM, SC), and organic silt with slight plasticity (ML). Soils of the Dale-Canadian-Port association are classified as clay and silt of slight to medium plasticity (CL, ML), and silty sand (SM).

Geologic units which outcrop at various locations within the Tinker AFB region are comprised of Quaternary Alluvium and Terrace deposits, Hennessey Group, and the Garber-Wellington Formation. Quaternary alluvium, present along portions of Crutch Creek and Soldier Creek, consists of unconsolidated, interfingered lenses of sand, silt, clay and gravel. The terrace deposits, which were laid down by ancient streams, consist mostly of lenticular beds of sand, silt, clay, and gravel. The Hennessey group, a maximum, of 35 feet thick at Tinker AFB but attains thicknesses up to 750 feet regionally, is composed of deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy shale. It is present under surficial soils on the southern portion of the Base. Units comprising this Group are the Kingman Siltstone and the Fairmont Shale. The Garber-Wellington Formation, which outcrops at some locations on the northern portion of the Base is comprised of the Garber Sandstone and the Wellington Formation. The Garber Sandstone is a deep-red to reddish orange, massive and cross bedded, fine grained sandstone interbedded and interfingered with red shale and siltstone. It is approximately 500 feet thick in the vicinity of Tinker AFB. The Wellington Formation, which is often difficult to distinguish from the overlying Garber Sandstone, is a deep-red to reddish orange, massive and cross bedded, fine grained sandstone interbedded with red, purple, maroon, and gray shale. Because the Garber Sandstone and Wellington Formation are not easily distinguished from one another on the basis of lithology or groundwater, they are discussed as a single formation. Under the Hennessey Group and the Garber-Wellington are the Chase, Council Grove, and Admire Groups which consist of beds of fine-grained, cross-bedded sandstone, shale, and thin limestone (Wood and Burton, 1968). The Hennessey Group, Garber-Wellington Formation and the Chase, Council Grove and Admire Groups were deposited during the Permian

period (230 to 280 million years ago) and are typical of redbed deposits characteristic of that period.

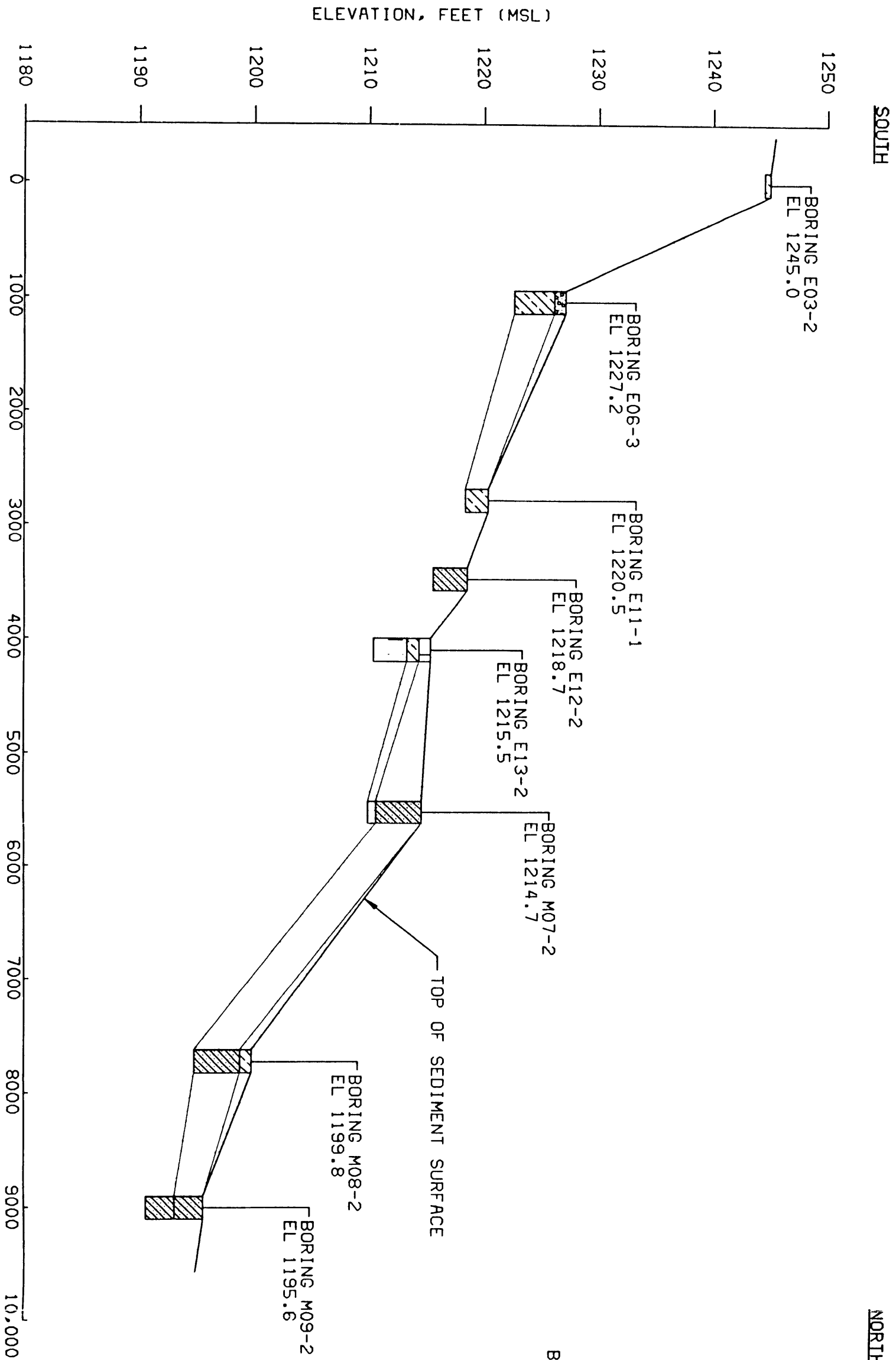
Tinker AFB lies within a tectonically stable area. No major faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area are nearly flat-lying. The reported regional dip is to the west at about 50 feet per mile (USGS, 1989).

3.3.2 Site Geology






Soldier Creek drains a geographic area which has both the Hennessy Group and the Garber-Wellington Formation at the surface. Overlying the bedrock in the site are the terrace deposits of former drainage system development and the alluvium related to the present drainage activity.

The Phase I and II field investigations at the Soldier Creek Site focused on the sediments in Main, East, and West Soldier Creek. Figures 3-5 (page 3-12) and 3-6 (page 3-13) present sediment profiles of East Soldier Creek, Main Soldier Creek, and West Soldier Creek. Boring logs from the Phase II sediment sampling locations used to construct the profiles are presented in Appendix E (Volume 3). Nine borings were augered to a depth of approximately five feet within Main Soldier Creek, with three borings drilled across the creek at each of the three sampling locations (M07, M08, M09). The subsurface sediment profile indicated predominantly olive to reddish brown sandy lean clay (CL), olive brown sandy silty clay (CL-ML), and silty clayey sand (SC-SM). There was no visual hydrocarbon staining within Main Soldier Creek. Soils and sediments observed in the field could not be correlated with specific regional soil series descriptions.

Sixteen borings at five sampling locations (E03, E06, E11, E12, and E13) were augered to depths between one-half foot and five feet due to impenetrable sediment and bedrock in East Soldier Creek. The subsurface sediment profile indicated predominantly black organic soil with sand (OL-OH), loose gravel with sand (GP), sandy silty clay (CL-ML), and sandy lean clays (CL). There was visual hydrocarbon staining in the sediment at sampling locations E06, E11, and E12. This hydrocarbon staining was observed in the sediment at these locations from the surface to bedrock.



LEGEND

-  SILTY CLAY
-  SANDY CLAY/CLAYEY SAND
-  SANDY SILT
-  SANDY GRAVEL
-  ORGANIC SOIL WITH SAND

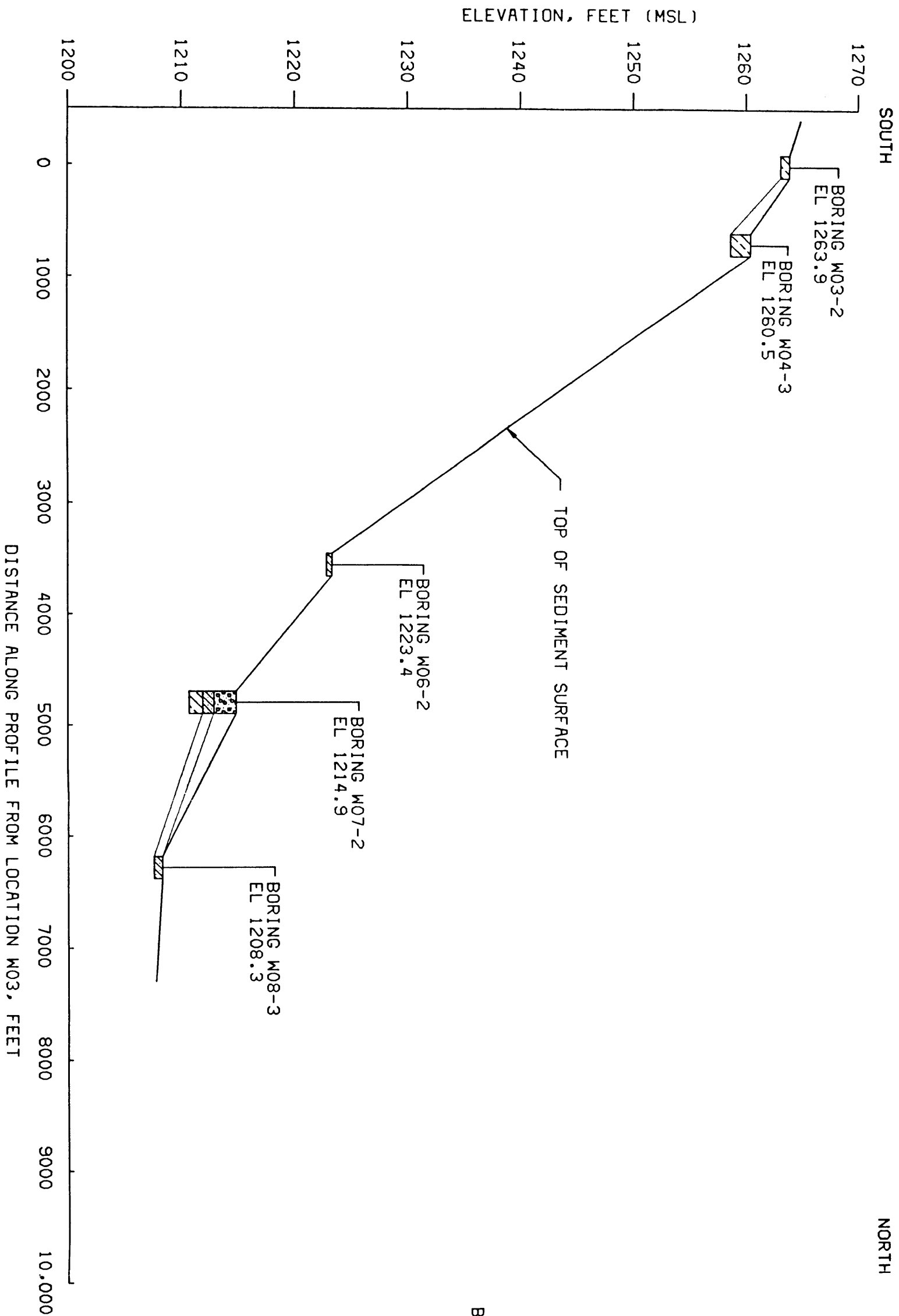
BORING M07-2
BORING NUMBER
LOCATION NUMBER
CREEK BRANCH DESIGNATION
(M=MAIN, E=EAST, W=WEST)

NOTES






1. ELEVATION DATA FROM PHASE 1 LOCATIONS.
2. ELEVATIONS SHOWN CORRESPOND TO THE TOP OF CREEK BED.
3. BORINGS WERE DRILLED AT DESIGNATED SAMPLE LOCATIONS.

SCALE:
HORIZONTAL: 1"=1000'
VERTICAL: 1"=10'

SCALE
HORIZONTAL: 1"=1000'
VERTICAL: 1"=10'



LEGEND

-  SILTY CLAY
 -  SANDY CLAY/CLAYEY SAND
 -  SANDY SILT
 -  SANDY GRAVEL
 -  ORGANIC SOIL WITH SAND
- BORING W07-2
- BORING NUMBER
- LOCATION NUMBER
- CREEK BRANCH DESIGNATION
(M=MAIN, E=EAST, W=WEST)

NOTES

1. ELEVATION DATA FROM PHASE 1 LOCATIONS.
2. ELEVATIONS SHOWN CORRESPOND TO THE TOP OF CREEK BED.
3. BORINGS WERE DRILLED AT DESIGNATED SAMPLE LOCATIONS.

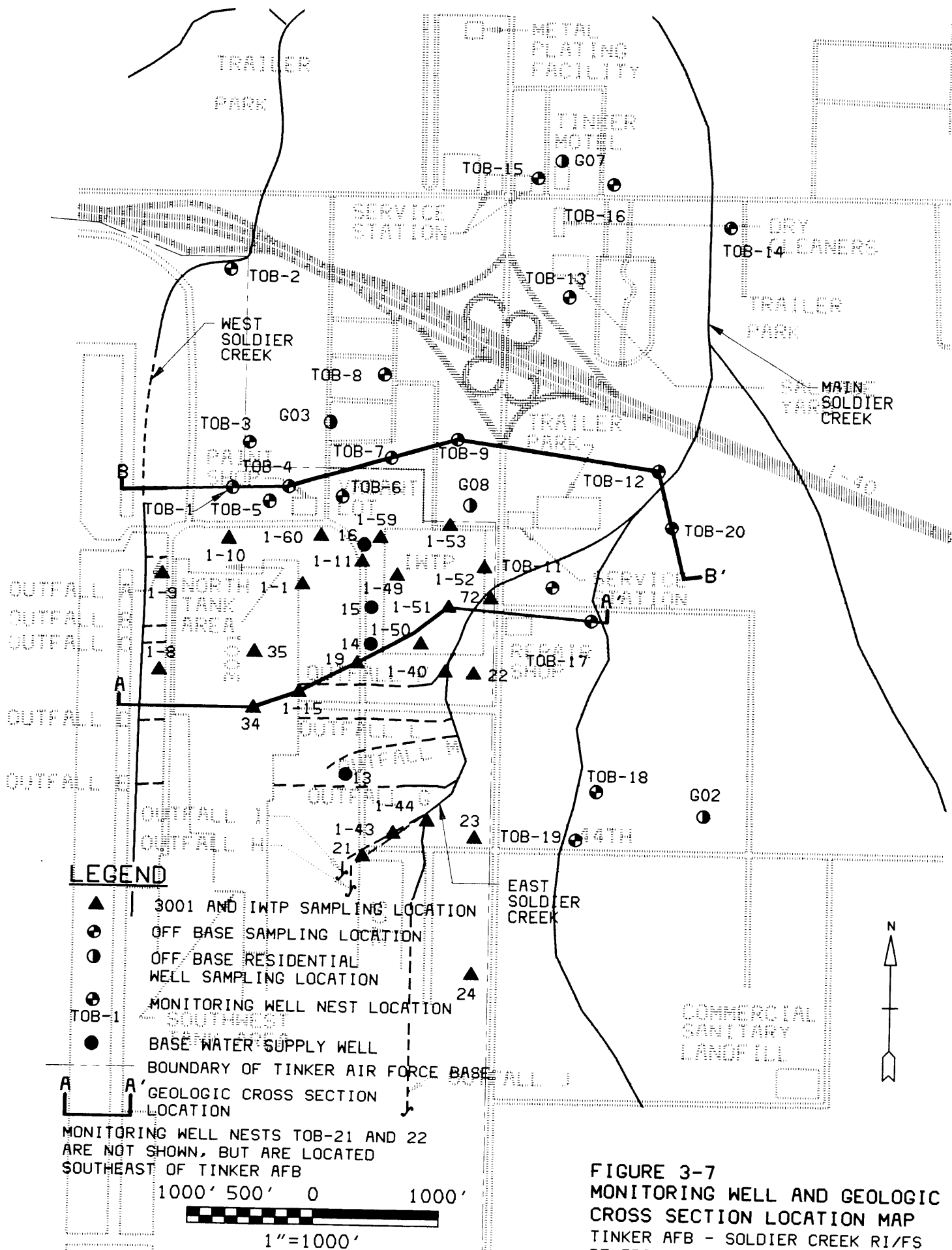
FIGURE 3-6
WEST SOLDIER CREEK SEDIMENT PROFILE
TINKER AFB-SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

Fifteen borings at five sampling locations (W03, W04, W06, W07, and W08) were augered in West Soldier Creek to a depth of only 2 feet due to impenetrable sediments and bedrock. The general soil profile consisted predominantly of very hard reddish brown sandy silty clay (CL-ML) and clayey sand (SC), with minor amounts of gravel and organics. There was no visual hydrocarbon staining within West Soldier Creek.

Thirteen borings at four background locations (C01, C02, C03, and D01) were augered to a depth of five feet along two eastern unnamed tributaries to Main Soldier Creek. The subsurface sediment profile consisted predominantly of sand (SP), clayey sand (SC), sandy lean/fat clay (CL-CH), silty clayey sand (SC-SM), and sandy lean clay (CL). There was no visual indication of hydrocarbon staining at any of the background locations.

The geology at Tinker AFB was studied in detail during previous investigations IWTP RI Report-Tinker AFB (Tulsa COE, 1991a), Building 3001 RI Report (Tulsa COE, 1988a), and Off-Base Groundwater Investigations Northeast of Base (Tulsa COE, 1991b)]. Several borings were drilled and monitoring wells installed within and outside the boundaries of Tinker AFB. Forty-five monitoring wells and seven piezometers were used to characterize the geology and hydrogeology for the IWTP remedial investigation. Sixty wells in twenty well nests, addressed in the Off-Base reports and 29 wells, addressed in the Building 3001 report, are shown on Figure 3-7 (page 3-15). Two additional well nests, TOB-21 and TOB-22, are not shown on the figure because the wells are located southeast of the Base. The boring logs and groundwater elevation data associated with the monitoring wells used for the IWTP RI, Building 3001 RI, and the Off-Base Groundwater Investigation reports were used to characterize the Soldier Creek Site geology and hydrogeology. Boring logs for all these wells are included in Appendix E (Volume 3).

Most of the borings drilled in the site area penetrated interbedded discontinuous units of sandstone, siltstone, and shale varying in thickness from 1 to 30 feet indicating the complexity of stratigraphy across the site. Geologic cross-sections A-A' and B-B' shown on Figures 3-8 (page 3-16) and 3-9 (page 3-17), respectively present the stratigraphic variation onsite. The locations of cross-sections A-A' and B-B' are shown on Figure 3-7 (page 3-15).



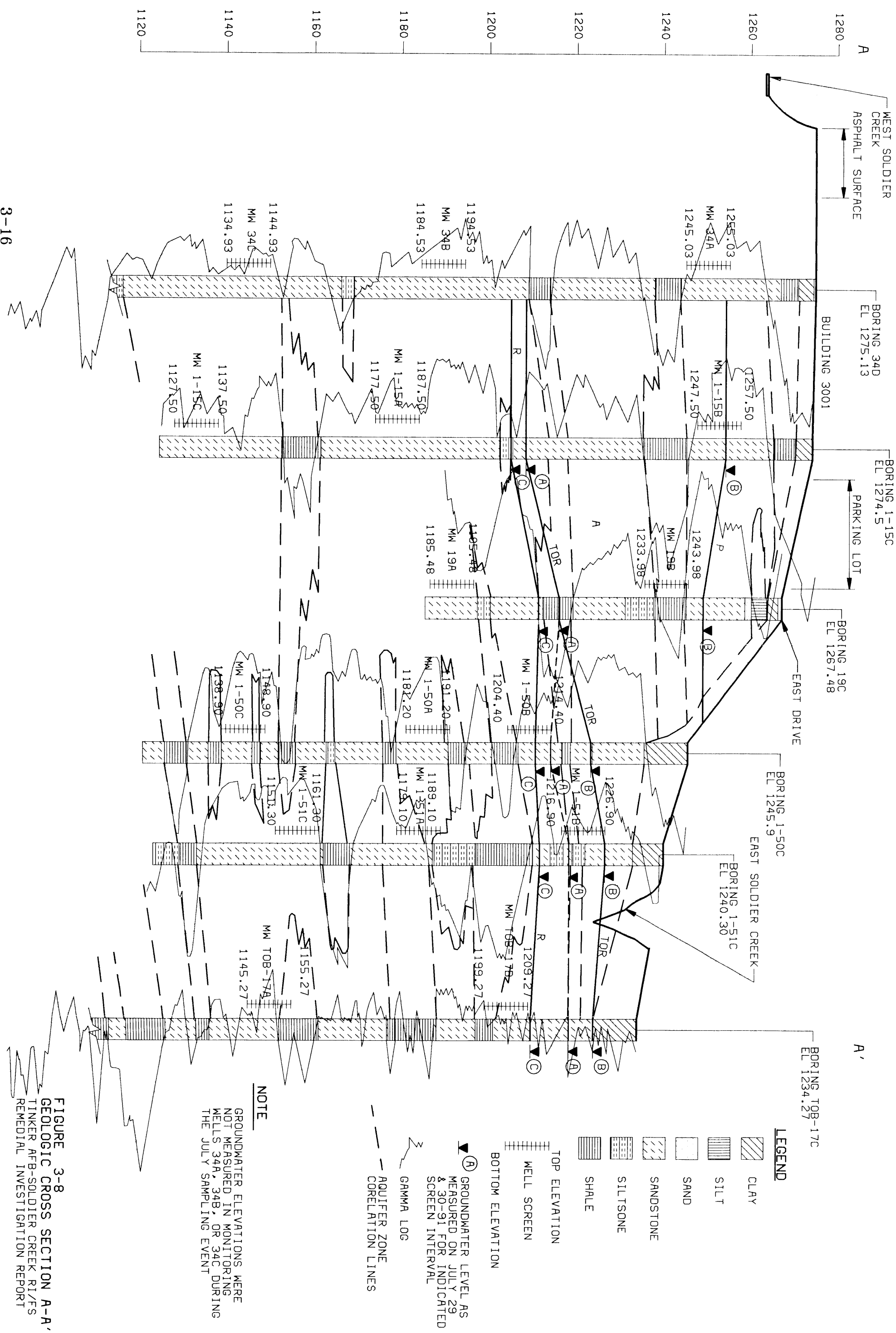


FIGURE 3-8
GEOLOGIC CROSS SECTION A-A'
TINKER AFB-SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

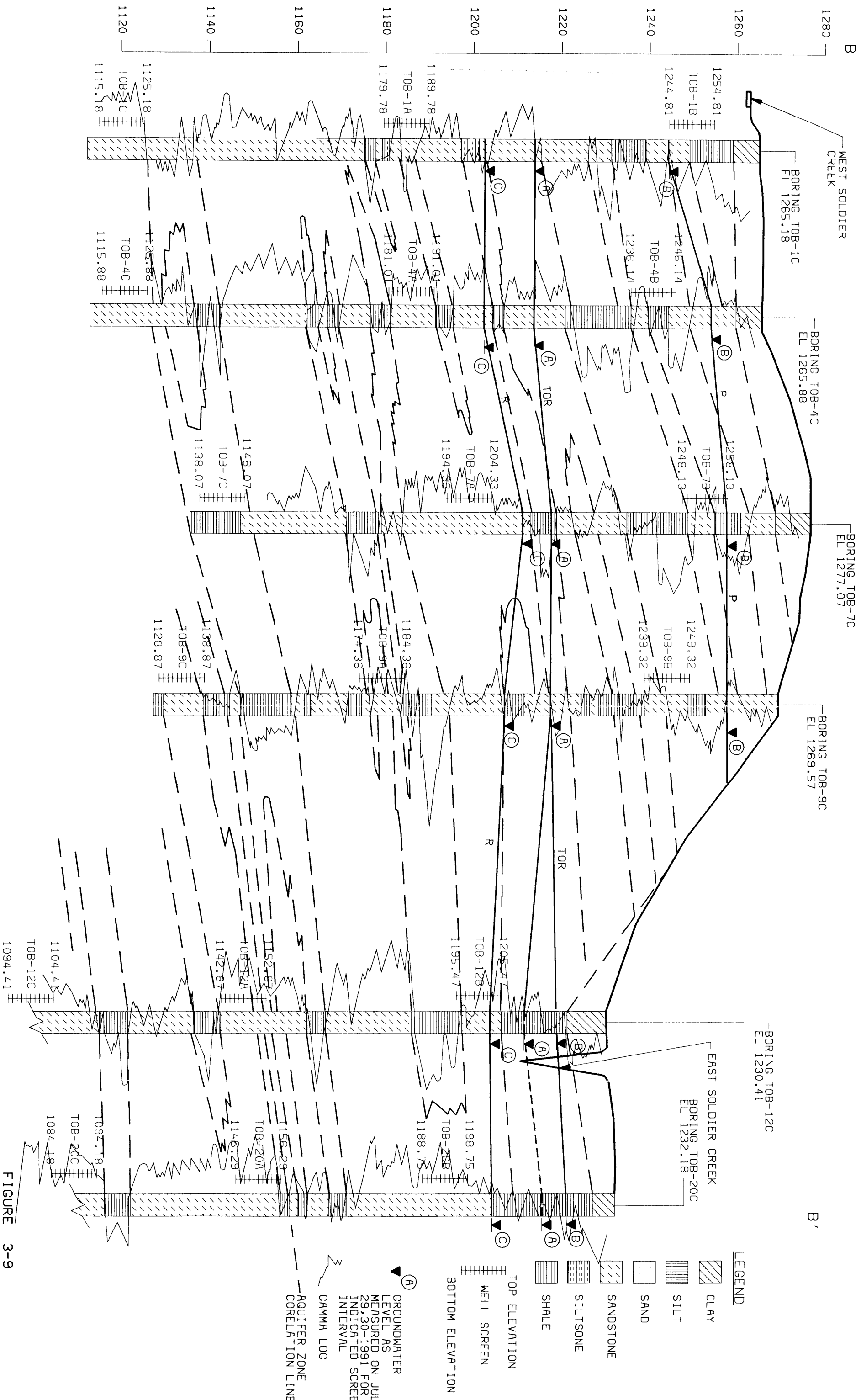


FIGURE 3-9
GEOLOGIC CROSS SECTION B-B'
TINKER AFB-SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

Additional cross-sections of Tinker AFB can be found in the IWTP RI, Building 3001 RI and the Off-Base Groundwater Investigation reports. Cross-sections A-A' and B-B' are representative of the complex stratigraphy onsite. Bedrock at the Soldier Creek Site is covered by a thin veneer of soil ranging in thickness from 2 to 15 feet. Surface soils onsite are comprised of sand, silt, clay, and gravel. Erosion and construction has exposed the bedrock at several locations onsite and within the creek.

Bedrock units encountered in borings drilled onsite consisted of interbedded units of sandstone, siltstone, and shale from the Hennessy Group and Garber-Wellington Formations. The sandstones are generally very fine to medium grained, poorly to moderately well sorted, and red-brown in color. The siltstones are soft to moderately hard, poorly to moderately cemented, shaley and red-brown. The shales are soft, silty, blocky, and red-brown.

Cross-sections A-A' (Figure 3-8, page 3-16) and B-B' (Figure 3-9, page 3-17) show a layer of sand, silt, clay, and clayey fill material present in the upper 5 to 10 feet below the ground surface. Underlying this clay is a sequence of interbedded and lenticular sandstones and shales with a westerly dip component.

3.4 Regional and Site Hydrogeology

The following section presents information regarding the regional and site-specific hydrogeologic conditions at the Soldier Creek Site.

3.4.1 Regional Hydrogeology

Tinker AFB and Soldier Creek lie within the limits of the Garber-Wellington Groundwater Aquifer Basin as shown on Figure 3-4 (page 3-9). The Wellington Formations and the Garber Sandstone, along with the Chase, Council Grove, and Admiral Groups, comprise what is commonly referred to as the Garber-Wellington Aquifer. The Garber-Wellington Aquifer, also referred to as the Central Oklahoma Aquifer, will be addressed as the Garber-Wellington in this report to remain consistent with past investigations.

The Garber-Wellington Aquifer is overlain by a thin discontinuous sequence of Hennessey Group formations in the southern half of the Base with the Hennessey formations thickness and areal coverage increasing to the west. The sandstones, siltstones and shales constituting the aquifer tend to be loosely cemented with a collective thickness of 1,000 feet. Regionally, the groundwater flows to the southwest in the Garber-Wellington under both confined and unconfined conditions with the overlying alluvium and terrace deposits, as well as, the formations comprising the Garber-Wellington being part of the same groundwater flow system (USGS, 1989).

Recharge of the Garber-Wellington is accomplished principally by rainfall and surface water infiltration from streams. Because the Garber-Wellington outcrops in the Tinker AFB area, it is assumed that the Base is situated in a recharge zone (Engineering Science, 1982) for the Garber-Wellington.

Most of the groundwater used from the region for industrial and commercial purposes is pumped from the producing zone of the Garber-Wellington located at a depth of 250 to 700 feet. The producing zone is relatively permeable with pump test results from wells in the nearby cities of Norman and Edmond indicating permeabilities of about 10^{-3} cm/s. The producing zone underlies the shallower aquifer zones under Tinker AFB. A downward vertical component of groundwater flow exists in the producing zone (Tulsa COE, 1991b). The water becomes saline near the Base of the formation, and wells drilled through the fresh water zone have to be partially backfilled to be usable.

Production wells from nearby Midwest City and Del City pump from a depth of about 550 feet at rates of approximately 250 gallons per minute. Midwest City, just north of Tinker AFB, has 28 wells in their system, and although they do not all operate simultaneously, the well system pumps about one million gallons per day. Residential usage is generally obtained from depths shallower than 200 feet. There are 23 water supply wells at Tinker AFB which pump approximately one million gallons per day from the producing zone (Figure 3-7, page 3-15).

Regionally, the Garber-Wellington Aquifer is the single most important source of potable groundwater in the Oklahoma City metropolitan area. The quality of groundwater derived from the Garber-Wellington Aquifer is generally good, although

wide variations in the quality parameters such as hardness, sulfate, chloride, fluoride, nitrate, or dissolved solids, are known to occur (Wood and Burton, 1968). A saline zone, encountered at depths greater than 900 feet below ground surface is present beneath Tinker AFB and its immediate surrounding area.

3.4.2 Site Hydrogeology

The local groundwater flow direction and gradient is complex due to the highly variable stratigraphy. The Garber-Wellington is, as mentioned in Section 3.4.1, a highly complex aquifer with a vertical downward gradient and lenticular beds of sandstone and shale. For the purpose of determining extent and movement of contaminated groundwater at the remedial sites on Base, a conceptual model of this aquifer has been developed. Three zones are defined in this model as follows:

<u>Zone</u>	<u>Definition</u>
Top of Regional Zone	First encounter of groundwater. Second encounter if perched water is present.
Regional Zone	Water levels about 80 feet and wells to an approximate depth of 150 feet.
Producing Zone	Wells 300 to 500 feet in depth, where major thicknesses of sandstone are present and most municipal and industrial wells are located.

Overlying the Garber-Wellington Aquifer is a shallow, perched aquifer, which is separated from the Garber-Wellington by low permeability strata and an unsaturated interval. Thus, there are two aquifers present on the Base, with the lower being divided into three zones.

One hundred and thirty monitoring wells were installed for the remedial investigations for the Industrial Wastewater Treatment Plant (Tulsa COE, 1991a), Building 3001 (Tulsa COE, 1988a), and Off-Base Groundwater Investigations Northeast of Base (Tulsa COE, 1991b). These wells were used to assess the site

hydrogeology of Soldier Creek [see Figure 3-7 (page 3-15) for the locations of the wells]. Thirty-one wells were installed in the perched aquifer, 63 wells were installed in the top of regional aquifer zone, and 36 wells were installed in the regional aquifer zone. Groundwater elevations were measured in several monitoring wells on July 29 and 30, 1991, and the results are presented for each aquifer zone in Tables 3-1 (page 3-22), 3-2 (page 3-23), and 3-3 (page 3-24). In general, the rationale, for placement of well screens for each of the investigations listed above, was to identify and quantitatively analyze the aquifer zones under Tinker AFB. Each well screen was located within an individual zone to be representative of that zone. None of the well screens were specifically located within any portion of the aquifer zones for the sole purpose of delineating stratification of individual contaminants.

Shallow alluvial and residual water bearing units exist within Tinker AFB and the surrounding area where zones of alluvium border streams and where shallow, sandy, residual soil collects precipitation. At Tinker AFB, sandy residual soils overlying bedrock form such units. These water bearing units may be recharged directly by precipitation and gradually lose this water as it percolates into local streams and underlying bedrock aquifers. Although the primary hydrogeologic objective of the Soldier Creek RI was to address interactions between Soldier Creek and site aquifers, as well as the impact of this relationship on contaminant transport at the site, it should be noted that discontinuity of permeable and impermeable strata at the Soldier Creek Site strongly influences site hydrogeology. The absence of impermeable strata between aquifer zones allows free mixing of groundwater between aquifer zones within the Garber-Wellington and vadose zone transport between the perched aquifer and the Garber-Wellington. This mixing of site groundwater could supercede other contaminant transport mechanisms, such as Soldier Creek, at the site.

TABLE 3-1
PERCHED AQUIFER GROUNDWATER ELEVATIONS
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

WELL NO.	COORDINATES		TOP OF WELL ELEVATION (FT)	SCREEN INTERVAL (FEET BELOW GROUND SURFACE)	GROUNDWATER ELEVATION (FT)(1)
	NORTHING	EASTING			
TOB-1B	156,740.899	2,185,535.285	1,264.81	10-20	1,243.5
TOB-2B	158,361.499	2,185,570.085	1,234.35	25-35	1,218.5
TOB-3B	157,052.999	2,185,656.885	1,254.38	18-28	1,231.0
TOB-4B	156,623.999	2,186,069.885	1,266.14	20-30	1,253.4
TOB-5B	156,466.999	2,185,748.385	1,266.88	14-24	1,258.3
TOB-6B	156,593.499	2,186,476.585	1,272.18	26-36	1,253.4
TOB-7B	156,933.199	2,186,731.085	1,277.13	19-29	1,258.5
TOB-8B	157,463.199	2,186,720.685	1,274.55	10-20	1,259.1
TOB-9B	157,000.999	2,187,330.185	1,269.32	20-30	1,256.9
TOB-10B	DATA NOT AVAILABLE				1,254.6 (2)
TOB-21B	149,351.201	2,191,145.972	1,270.31	45-55	1,231.4
TOB-22B	150,983.001	2,190,711.272	1,266.45	30-40	1,230.7
1-1B	155,964.54	2,186,012.42	1,275.15	23-33	1,257.5
1-10B	156,325.48	2,185,419.65	1,271.96	23.5-33.5	1,253.0
1-11B	156,155.05	2,186,488.22	1,270.72	23.5-33.5	1,252.4
1-15B	155,119.00	2,186,012.00	1,277.70	17.0-27.0	1,254.6
1-60B	156,316.36	2,186,147.83	1,271.13	12.4-22.4	1,258.4
19B	155,320.39	2,186,486.64	1,270.69	23.5-33.5	1,249.5
34A	154,991.00	2,185,726.00	1,275.13	20.1-31.1	N/A
35A	154,991.00	2,185,726.00	1,275.13	20.2-30.2	1,225.9 (2)
23B	153,937.59	2,187,372.26	1,269.24	23.0-33.0	1,246.9
1-43A	153,916.00	2,186,750.00	1,267.40	25.7-30.7	1,240.5
1-43B	153,916.00	2,186,750.00	1,267.40	7.2-12.2	DRY
1-44B	DATA NOT AVAILABLE		1,261.80	16.8-21.8	1,242.0 (2)
1-8B	155,051.38	2,184,964.48	1,277.08	26.9-31.5	1,257.2
1-7B	154,604.32	2,184,919.21	1,275.77	21.8-31.8	1,258.0
25B	153,496.74	2,184,900.86	1,274.78	15.0-25.0	1,252.7
1-9B	155,967.70	2,184,946.75	1,275.55	23.0-33.0	1,256.1
1-26	156,053.00	2,185,152.00	1,275.20	6.8-16.8	1,259.4
21B	DATA NOT AVAILABLE		1,269.00	23.4-33.4	1,253.4 (2)
1-59B	DATA NOT AVAILABLE				1,255.0

(1) Elevations measured on July 29 and 30, 1991.

(2) Elevations were measured at other times.

TABLE 3-2
TOP OF REGIONAL AQUIFER ZONE GROUNDWATER ELEVATIONS*
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

WELL NO.	COORDINATES		TOP OF WELL ELEVATION (FT)	SCREEN INTERVAL (FEET BELOW GROUND SURFACE)	GROUNDWATER ELEVATION (FT)(1)
	NORTHING	EASTING			
TOB-1A	156,741.599	2,185,561.385	1,264.78	75-85	1,214.4
TOB-2A	158,359.699	2,185,554.585	1,234.72	73-83	1,206.0
TOB-3A	157,053.099	2,185,667.585	1,254.34	75-85	1,213.1
TOB-4A	156,633.899	2,186,070.285	1,266.01	75-85	1,214.0
TOB-5A	156,466.999	2,185,761.185	1,266.76	80-90	1,212.9
TOB-6A	156,583.399	2,186,474.385	1,271.95	70-80	1,217.7
TOB-7A	156,933.399	2,186,746.285	1,277.33	73-83	1,218.5
TOB-8A	157,474.399	2,186,720.785	1,274.22	67-77	1,216.9
TOB-9A	157,036.199	2,187,332.385	1,270.36	86-96	1,218.0
TOB-10A	DATA NOT AVAILABLE				1,217.4 (2)
TOB-11A	155,967.001	2,188,038.672	1,233.65	64-74	1,222.3
TOB-11B	155,969.001	2,188,052.972	1,233.47	9-19	1,225.0
TOB-12A	157,263.299	2,188,461.885	1,230.87	78-88	1,211.9
TOB-12B	157,257.899	2,188,476.085	1,230.47	25-35	1,211.4
TOB-13A	158,100.901	2,187,916.812	1,257.34	75-85	1,213.3
TOB-13B	158,143.301	2,187,876.972	1,258.49	57-67	1,215.2
TOB-14A	158,882.901	2,189,432.472	1,222.97	86-96	1,214.8
TOB-14B	158,903.101	2,189,435.772	1,223.41	15-25	1,215.6
TOB-15A	159,189.901	2,187,992.072	1,243.20	71-81	1,210.7
TOB-15B	159,162.201	2,187,992.772	1,243.10	33-43	1,210.9
TOB-16A	159,234.401	2,188,449.272	1,235.26	75-85	1,209.6
TOB-16B	159,234.601	2,188,434.572	1,235.54	35-45	1,209.4
TOB-17A	155,638.301	2,188,316.272	1,234.05	79-89	1,218.6
TOB-17B	155,639.201	2,188,332.172	1,234.22	25-35	1,224.6
TOB-18A	154,529.701	2,188,274.372	1,243.65	75-85	1,220.8
TOB-18B	154,538.601	2,188,273.427	1,243.79	38-48	1,226.3
TOB-19A	153,846.201	2,188,220.072	1,255.23	77-87	1,221.9
TOB-19B	153,855.601	2,188,219.572	1,254.89	40-50	1,222.6
TOB-20A	156,627.301	2,188,473.872	1,232.39	76-86	1,213.1
TOB-20B	156,615.801	2,188,471.372	1,231.75	33-43	1,220.5
TOB-21A	149,356.601	2,191,128.072	1,270.13	92-102	1,222.2
TOB-22A	150,991.201	2,190,708.872	1,266.18	86-96	1,226.8
1-1A	155,964.54	2,186,012.42	1,275.42	88.0-98.0	1,210.4
1-10A	156,322.71	2,185,404.36	1,272.92	88.0-98.0	1,209.1
1-11A	156,129.73	2,186,489.07	1,270.52	88.0-98.0	1,211.5
1-15A	155,130.00	2,186,012.00	1,277.50	87.0-97.0	1,208.1
1-49A	155,923.85	2,186,838.08	1,254.67	47.0-57.0	1,216.8
1-49B	155,927.08	2,186,802.34	1,257.78	27-37	1,224.0
1-50A	155,559.91	2,186,920.77	1,247.49	54.7-64.7	1,214.4
1-50B	155,560.35	2,186,909.04	1,247.96	31.5-41.5	1,223.7
1-51A	155,795.46	2,187,184.38	1,243.31	51.2-61.2	1,218.6
1-51B	155,777.21	2,187,184.60	1,242.61	13.4-23.4	1,226.8
1-52A	155,994.83	2,187,439.59	1,236.39	49.9-59.9	1,221.3
1-52B	155,984.27	2,187,442.82	1,236.95	8.4-18.4	1,226.0
1-53A	156,314.14	2,187,197.13	1,250.15	49.5-59.5	1,219.3
1-53B	156,314.32	2,187,180.20	1,251.52	18.0-28.0	1,227.8
1-59A	156,313.42	2,186,669.65	1,267.13	50.0-60.0	1,255.0 (2)
1-60A	156,317.48	2,186,165.38	1,271.06	54.0-64.0	1,216.5
19A	155,300.70	2,186,484.00	1,271.38	72.0-82.0	1,216.2
22A	155,259.30	2,187,384.80	1,256.10	47.0-57.0	1,225.0
22B	155,898.30	2,187,439.20	1,254.90	23.5-33.5	1,225.9
34B	154,998.00	2,185,726.00	1,275.12	80.6-90.6	N/A
35B	155,421.00	2,185,725.00	1,275.10	80.2-90.2	N/A
21A	153,841.11	2,186,498.45	1,271.25	80.0-90.0	1,210.9
23A	153,935.21	2,187,392.92	1,270.20	105.0-115.0	1,216.9
1-7A	154,602.89	2,184,906.84	1,275.70	97.0-107.0	1,202.8
1-8A	153,935.21	2,184,963.26	1,277.33	106.2-116.2	1,199.8 (2)
1-9A	155,060.56	2,184,947.27	1,275.38	110.0-120.0	1,203.9
24A	153,757.90	2,187,442.70	1,285.00	92.0-102.0	1,211.1
72	155,898.39	2,187,439.24	1,232.20	5.1-15.1	N/A
1-40	155,200.00	2,187,085.00	1,237.50	9.3-12.3	1,225.6
1-41	155,201.00	2,187,165.00	1,247.60	20.2-23.2	1,225.7
1-42	155,201.00	2,187,265.00	1,252.90	23.7-26.7	1,225.7

(1) Elevations measured on July 29 and 30, 1991.

(2) Elevations were measured at other times.

TABLE 3-3
REGIONAL AQUIFER ZONE GROUNDWATER ELEVATIONS
TINKER AFB – SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

WELL NO.	COORDINATES		TOP OF WELL ELEVATION (FT)	SCREEN INTERVAL (FEET BELOW GROUND SURFACE)	GROUNDWATER ELEVATION (FT)(1)
	NORTHING	EASTING			
TOB-1C	156,741.699	2,185,516.485	1,265.18	140-150	1,203.1
TOB-2C	158,357.699	2,185,537.485	1,234.44	130-140	1,203.7
TOB-3C	157,053.499	2,185,678.185	1,254.31	140-150	1,203.0
TOB-4C	156,642.199	2,186,070.885	1,265.88	140-150	1,203.6
TOB-5C	156,467.099	2,185,772.785	1,266.72	141-151	1,203.8
TOB-6C	156,575.399	2,186,472.885	1,271.99	125-135	1,211.5
TOB-7C	156,932.699	2,186,714.685	1,277.07	129-139	1,212.9
TOB-8C	157,483.599	2,186,721.485	1,274.39	134-144	1,210.1
TOB-9C	157,017.499	2,187,332.785	1,269.57	131-141	1,207.9
TOB-10C	DATA NOT AVAILABLE				1,203.8 (2)
TOB-11C	155,965.301	2,188,025.572	1,234.12	140-150	1,206.0
TOB-12C	157,252.699	2,188,489.885	1,230.41	126-136	1,201.5
TOB-13C	157,119.501	2,187,900.372	1,256.92	135-145	1,193.9 (2)
TOB-14C	158,865.201	2,189,430.072	1,222.77	139-149	1,173.7
TOB-15C	159,176.701	2,187,992.072	1,243.12	131-141	1,200.6
TOB-16C	159,218.201	2,188,449.072	1,235.46	131-141	1,202.6
TOB-17C	155,638.101	2,188,304.772	1,234.27	137-147	1,210.1
TOB-18C	154,519.801	2,188,275.272	1,243.95	124-134	1,210.5
TOB-19C	153,838.301	2,188,219.972	1,255.73	120-130	1,215.3
TOB-20C	156,636.701	2,188,476.472	1,232.18	138-148	1,206.7
TOB-21C	149,354.201	2,191,136.572	1,270.38	145-155	1,207.4
TOB-22C	151,000.201	2,190,707.272	1,266.77	130-140	1,223.0
1-10C	156,324.48	2,185,389.08	1,271.85	112.6-142.6	1,205.0
1-11C	156,107.06	2,186,491.74	1,271.84	112.0-122.0	1,211.3
1-15C	155,140.00	2,186,012.00	1,277.50	137.0-147.0	1,205.3
1-49C	155,912.39	2,186,803.76	1,257.45	107.0-117.0	1,206.9
1-50C	155,560.23	2,186,898.34	1,248.97	97.0-107.0	1,211.0
1-51C	155,785.35	2,187,184.89	1,243.13	79.0-89.0	1,212.0
1-52C	156,004.01	2,187,443.08	1,237.01	97.0-107.0	1,219.8
1-53C	156,312.60	2,187,189.16	1,251.28	97.0-107.0	1,208.5
1-59C	156,313.43	2,186,656.88	1,267.39	115.0-125.0	1,211.8
1-60C	156,313.51	2,186,175.48	1,271.06	113.5-123.5	1,210.9
19C	155,333.65	2,186,487.61	1,270.45	107.0-117.0	1,211.4
22E	155,290.00	2,187,384.00	1,254.93	122.0-132.0	1,214.7
34C	155,006.00	2,185,726.00	1,275.11	130.2-140.2	N/A
35C	154,428.00	2,185,725.00	1,275.11	120.2-130.2	N/A

(1) Elevations measured on July 29 and 30, 1991.

(2) Elevations were measured at other times.

The Soldier Creek Site is on a recharge area for the Garber-Wellington Aquifer. This gives a vertical, as well as a horizontal component to groundwater flow (Tulsa COE, 1991b). The uppermost water bearing zone, present over portions of the site, is the perched aquifer. On a regional scale, this aquifer is unconfined with a water table 15 to 30 feet below the ground surface at most locations and an average saturated thickness of 15 feet. The perched aquifer is absent locally due to erosion. It is unconfined and flows toward streams and topographic lows.

Alluvial deposits in some of the nearby streams appear to be hydrologically connected to the perched aquifer. The perched aquifer, recharged primarily by precipitation, discharges to area streams during periods of low flow, and may be recharged by the same streams during periods of high flow (Tulsa COE, 1988a).

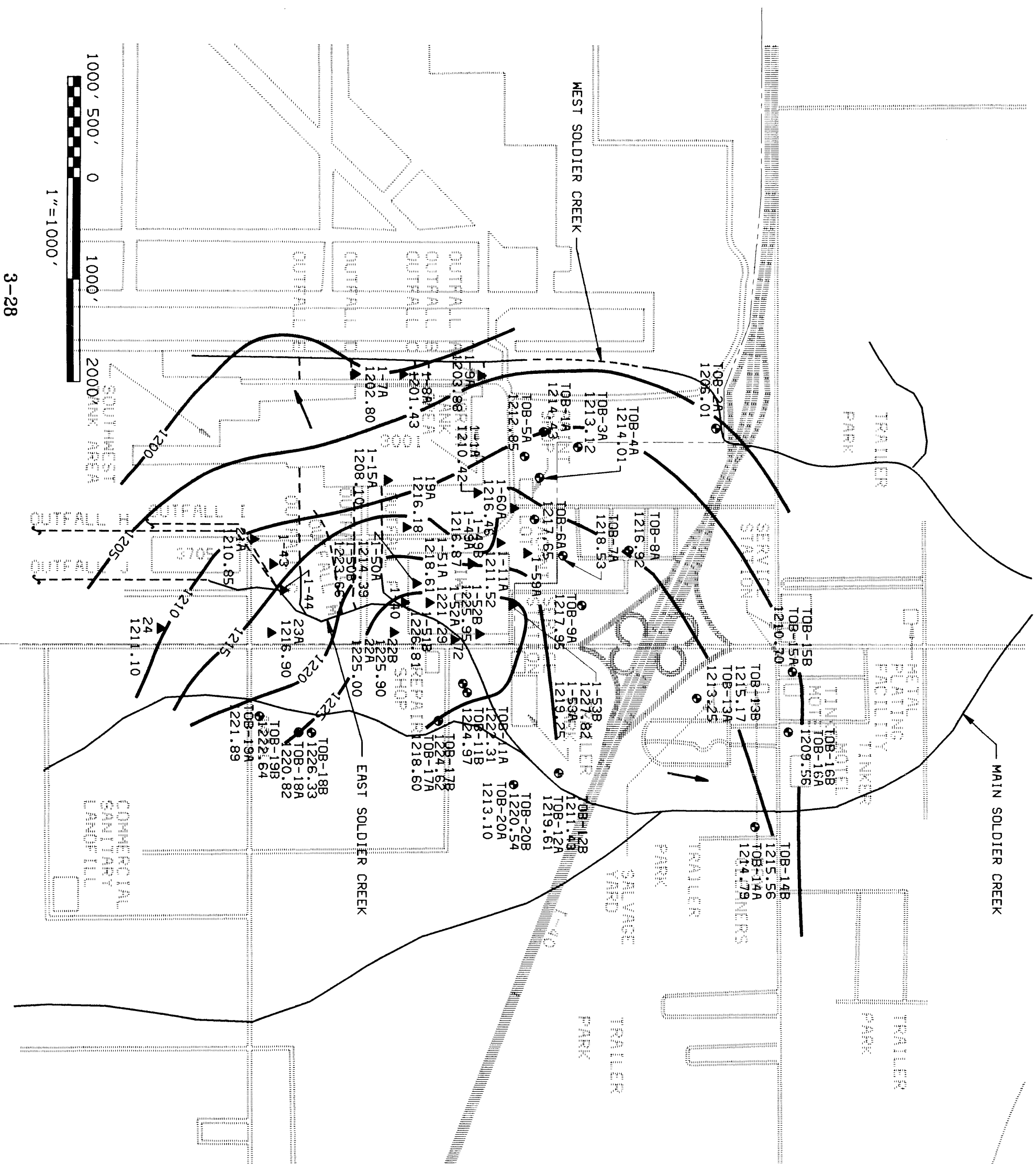
Vertical percolation rates of approximately six feet per year are estimated to occur between the perched aquifer and top of regional aquifer zone (Tulsa COE, 1988a). The monitoring wells in the perched aquifer and their observed groundwater elevations in July 1991 are shown in Table 3-1 (page 3-22). The meteorological conditions during the July time period are summarized in Subsection 3.1, Climatology.

The perched aquifer groundwater contours are presented on Figure 3-10 (page 3-27). The area around wells TOB-3, TOB-2, and 71 has been contoured as a continuous water surface with the perched water on-base, but may represent a separate perched water surface with no physical connection. The area around wells 1-43 and 1-44 has been contoured with the other perched wells in the area but may represent a slightly deeper stratum with a lower head than the surrounding wells. Additional data is needed to clarify these points. The groundwater contours show a groundwater high under Building 3001 which extends to the northeast. The direction of groundwater flow from this high is semi-radially to the northwest, north, northeast and east. These results are consistent with groundwater flow patterns reported in the Off-Base Groundwater Investigations Northeast of Base report (Tulsa COE, 1991b). Based on slug and laboratory tests, the average permeability for the perched aquifer in this vicinity is 7.6×10^{-4} cm/sec.

The top of regional aquifer zone is present from 50 to 80 feet below the ground surface. The top of regional aquifer zone is characterized as a semi-confined, leaky aquifer (Tulsa COE, 1991b). Table 3-2 (page 3-23) lists the monitoring wells in the top of regional aquifer zone. Top of regional aquifer zone groundwater contours, based on July 1991 groundwater elevation measurements, are presented on Figure 3-11 (page 3-28). Regionally, the groundwater flow direction is towards the southwest. In the vicinity of Solder Creek, the groundwater flows to the northwest, west, and southwest from a high centered over East Solder Creek near its exit from the Base. As shown on the geologic sections, East Soldier Creek appears to be a recharge source for the top of regional zone. Based on slug tests and laboratory tests, the average permeability of this zone is about 9×10^{-4} cm/sec.

Underlying the top of regional aquifer zone is the regional aquifer zone. The regional aquifer zone is semi-confined and is present at depths approximately 110 to 175 feet below the ground surface. The saturated thickness of this zone is 75 to 90 feet. Regional aquifer zone contours, based on July 1991 groundwater elevation data, are presented on Figure 3-12 (page 3-30).

**FIGURE 3-10
PERCHED AQUIFER
GROUNDWATER CONTOURS
TINKER AFB - SOLDIER CREEK
REMEDIAL INVESTIGATION REPORT**



LEGEND

BOUNDARY OF TINKER AIR
FORCE BASE
3001 AND IWTP SAMPLING
LOCATION

OFF BASE SAMPLING LOCATION

TOB-1A
1243.53

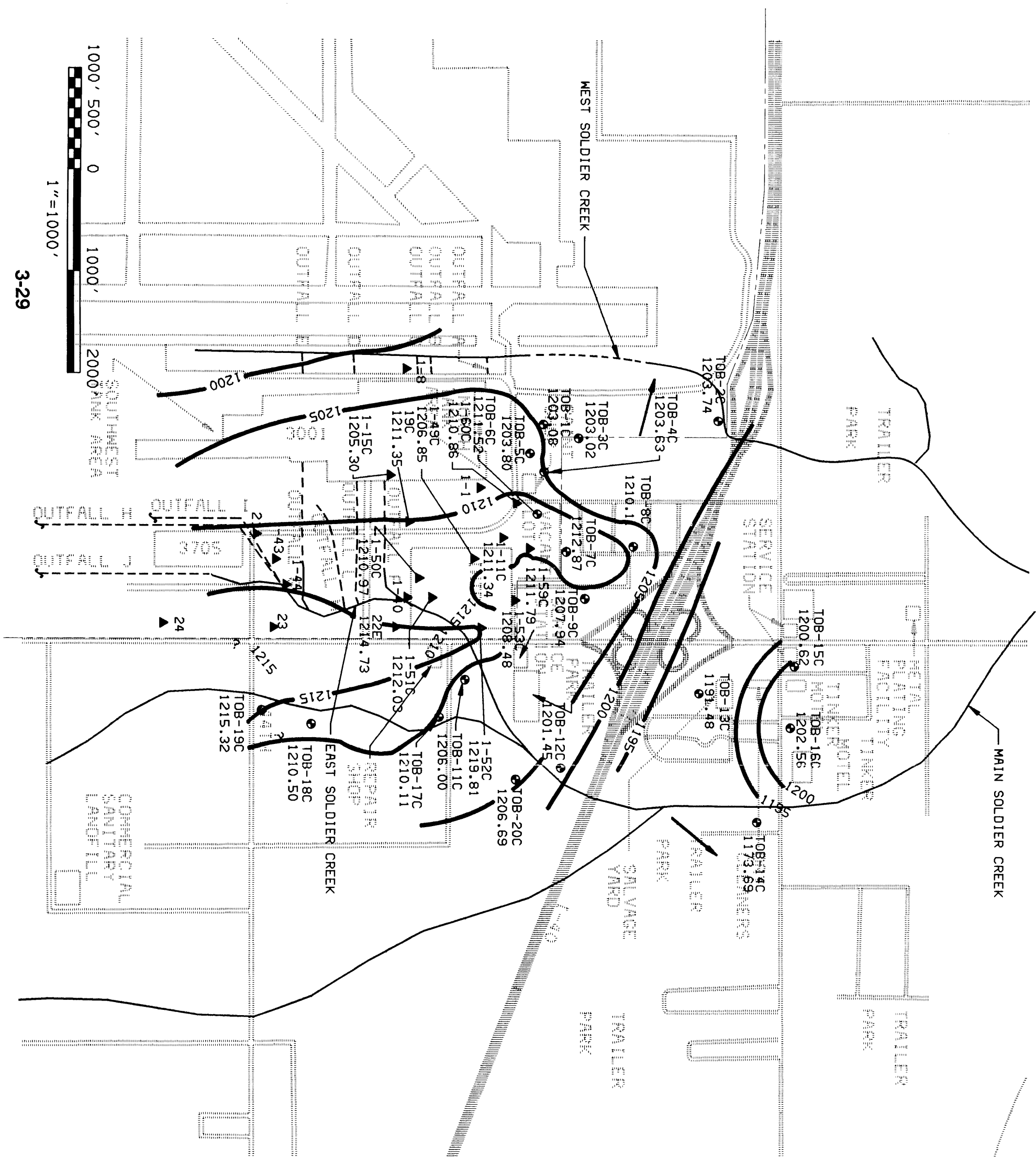
MONITORING WELL
WITH 7-30-91
GROUNDWATER ELEVATION
SHOWN (FEET ABOVE MSL)

POTENTIOMETRIC SURFACE IN
TOP OF REGIONAL AQUIFER
(FEET ABOVE MSL)

APPROXIMATE GROUNDWATER
FLOW DIRECTION

NOTE: GROUNDWATER ELEVATION
CONTOURS ARE BASED ON
WATER LEVELS MEASURED
JULY 29 AND 30, 1991.

**FIGURE 3-11
TOP OF REGIONAL AQUIFER ZONE
GROUNDWATER CONTOURS
TINKER AFB - SOLDIER CREEK
REMEDIAL INVESTIGATION REPORT**



LEGEND

BOUNDARY OF TINKER
AIR FORCE BASE

3001 AND IWTP
SAMPLING LOCATION

OFF BASE SAMPLING LOCAT

TOB-1C
1203.08

MONITORING WELL
WITH 7-30-91
GROUNDWATER ELEVATION
SHOWN (FEET ABOVE MSL)

POTENTIOMETRIC SURFACE
IN REGIONAL AQUIFER
(FEET ABOVE MSL)

APPROXIMATE GROUNDWATER
FLOW DIRECTION

NOTE:

GROUNDWATER ELEVATION
CONTOURS ARE BASED ON
WATER LEVELS MEASURED
JULY 29 AND 30, 1991.

**FIGURE 3-12
REGIONAL AQUIFER ZONE
GROUNDWATER CONTOURS
TINKER AFB - SOLDIER CREEK
REMEDIAL INVESTIGATION REPORT**

Groundwater in the regional aquifer zone flows toward the west, east, and northeast away from a groundwater high in the northeast portion of the Base. Vertical percolation rates of approximately 4 to 6 feet per year are estimated from the Building 3001 RI Report (Tulsa COE, 1988b). Based on slug tests and field tests, the average permeability is about 3.5×10^{-4} cm/sec. Table 3-4 (page 3-31) provides a comparison of groundwater model-derived transmissivity and storativity values to values calculated from a pump test performed as part of the Building 3001 investigations.

Based on geologic logs and cross-sections, impermeable layers between the top of regional aquifer and regional aquifer zones appear to be laterally discontinuous. At areas where an impermeable layer is absent there is direct hydraulic connection between the two zones. On a local scale, leakage between the top of regional aquifer zone and regional aquifer zone appears to be significant enough that these two zones may act as one water bearing unit. The groundwater high in the regional aquifer zone may be the result of increased recharge of the top of regional aquifer zone to the regional aquifer zone in this area.

3.5 Surrounding Land Use and Demographics

The population of Midwest City in 1980 was 49,559. The projected population for the year 2000 is estimated to be between 57,100 and 64,600. Between 1970 and 1980, a large decrease in population was seen between Midwest Boulevard and Douglas Boulevard and between southeast 15th Street and southeast 29th Street. This area is directly north of Tinker AFB. The decrease is attributed to the removal of the Glenwood Addition neighborhood located north of the Base. As of 1980, the median age of the population in Midwest City is 28.5 years, an increase of 4.3 years from

1960. In 1980, 7.2 percent of the population was over 65 years of age, an increase of 4.1 percent from 1960. In 1980, 8.2 percent of the population was under the age of 5 years, a decrease of 5.5 percent from 1960.

The median income of Midwest City residents in 1979 was \$17,537, which was greater than that for the residents of Oklahoma County and the state. In 1979, 22.8 percent of the households in Midwest City had an income of less than \$10,000 per year, 17.9

TABLE 3-4
TRANSMISSIVITY AND STORATIVITY DATA
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

	PERCHED AQUIFER	TOP OF REGIONAL AQUIFER ZONE	REGIONAL AQUIFER ZONE
Groundwater			
Model (1)			
Transmissivity (GPD/FT)	200-3200	1,000-30,000	2,900-13,000
Storativity	0.001	0.00001	0.00001
Pump Test (2)			
Transmissivity (GPD/FT)	300-2,800	1,700-37,600	2,100-8,300
Storativity	0.01-0.001	0.001-0.0001	0.00001-0.00000001

GPD/FT - Gallons Per Day Per Foot

(1) BVWST, 1991a

(2) Tulsa COE, 1990

percent had income of greater than \$30,000 per year. In the 1970s, the labor force of Midwest City increased, while the unemployment rate decreased. Public administration, which includes employment at Tinker AFB, had the largest amount of employment for an industrial group in Midwest City. Manufacturing, retail trade, and professional and related services also constituted a large percentage of the other industrial groups providing employment in Midwest City. Retail is the largest of the three categories of business in Midwest City: retail, service, and wholesale.

Tinker AFB lies within an area representing a transition from residential and industrial/commercial land use on the north and west to agricultural land use to the east and south. Soldier Creek and its branches, which flow northwest through the area, appears to be bordered mainly by recreational and residential areas with some areas supporting commercial and industrial land use (Midwest City, 1984 and Oklahoma City, date unknown). Drainage into Soldier Creek flows north from Tinker AFB, through mostly residential areas. Some industry such as a metal plating facility, and a dry cleaning facility are present within the drainage basin as well as commercial facilities such as gas stations, auto repair facilities, and a closed sanitary landfill. These facilities are shown on Figure 1-2 (page 1-4). In addition, three schools, Soldier Creek Elementary, Steed Elementary, and Monroney Junior High exist within the drainage basin. There are ten public parks within the general vicinity of Tinker AFB, including the Joe E. Barns, Fred F. Meyers, Kiwanis, and Lions Parks. A public golf course is also located north of the Base. Five trailer parks are located north and northeast of Tinker AFB.

The land use plan for the area immediately north of Tinker AFB, between Sooner Boulevard and Douglas Boulevard includes all levels of land use (Midwest City, 1985). The areas between Sooner Boulevard and Midwest Boulevard and east of Douglas Boulevard are zoned primarily for housing (single and multifamily units) and low to medium commercial use. The area between Midwest Boulevard and Douglas Boulevard is zoned primarily for heavy commercial and moderate to heavy industrial use.

3.6 Ecological Conditions

The following presents information of the different species of mammals, birds, insects, aquatic life, and plants present on and around Tinker AFB. Information was obtained from the "F16 Beddown Environmental Assessment" prepared by Argonne National Laboratories for Tinker AFB (Tulsa COE, 1988d), and from the Oklahoma Natural Heritage Inventory (ONHI, 1989).

Several federal threatened or endangered bird species may occasionally be present in the Tinker AFB area. The threatened species are the Arctic peregrine falcon and piping plover. The endangered species are the bald eagle, American peregrine falcon, whooping crane, and the interior population of the least tern. The potential for the presence of these species in the immediate vicinity of Tinker AFB is low because the preferred habitat and the known areas of congregation for these species are not located near the Base (Tulsa COE, 1988d).

The most common species of birds from the Oklahoma City area are the Canada goose, killdeer, rock dove, mourning dove, common night hawk, chimney swift, scissor-tailed flycatcher, American crow, American robin, European starling, common grackle, and the house sparrow. This area is in the central flyways for migratory waterfowl (Tulsa COE, 1988b).

Mammals common to habitats at Tinker AFB include the eastern fox, squirrel, thirteen-lined ground squirrel, plains pocket gopher, eastern cottontail rabbit, white-footed mouse, striped skunk, raccoon, opossum, Norway rat, and the house mouse. The habitats most suited for wildlife occur primarily in mowed grassy fields and undeveloped areas associated with drainages (Tulsa COE, 1988b).

Although no endangered plant species have been reported in the Tinker AFB area [Township 11 North (T11N), Range 2 West (R2W), Oklahoma County], three species should be given special attention because of potential endangered or threatened species listing in the future. Two populations of the Oklahoma Beardtongue (Penstemon oklahomensis) were confirmed within T11N, R2W, Oklahoma County. Because this plant species is suffering a decline in population due to loss of habitat, it is currently being studied to determine if it should be petitioned to include it on the

U.S. Fish and Wildlife Service's list of endangered or threatened species (ONHI, 1989). Ozark poverty grass (Sporobolus ozarkanus) and a sedge (Carex fissa) are candidate 2 species for federal listing as endangered or threatened species. Although no populations of Ozark poverty grass or Carex fissa are confirmed within T11N, R2W, Oklahoma County; this area is within the known range of the species (ONHI, 1989).

One species of insect which is unconfirmed in the area, but is likely to occur in a habitat similar to Oklahoma Beardtongue is the Prairie Mole Cricket (Gryllotalpa major). It is a candidate 2 species for federal listing (ONHI, 1989).

Creeks and ponds constitute the aquatic habitats on Tinker AFB. Ponds are managed for largemouth bass and channel catfish. Other fish that could be present in these habitats include red shiner, plains minnow, carp, black bullhead, green sunfish and bluegill (Tulsa COE, 1988d).

Most of the on-base vegetated areas are mowed and landscaped, and little natural habitat exists. The varieties of grass present include bluestem, poverty grass, triple lawn, and Johnson. Scattered trees and shrubs occur around many buildings, the golf course, and on less developed portions of the Base. The largest wood habitats occur along the watercourses. Woody species include oaks, elms, willows, cottonwoods, box elders, sycamores, redbuds, ashes, and sumacs (Tulsa COE, 1988b).

4.0 NATURE AND EXTENT OF CONTAMINATION

The purpose of this section is to present, evaluate, and interpret the results of chemical and physical analyses of samples collected during Phases I and II of the Soldier Creek RI, the Off-Base Groundwater Investigations Northeast of Base (Tulsa COE, 1991b), and the Industrial Wastewater Treatment Plant RI (Tulsa COE, 1991a). The discussion is divided into sediment, surface water, and groundwater presentations. The contract required detection limit (CRQL) for each analyte is listed in Appendix F (Volume 3). The term "not detected" means the analytical result concentration was below the instrument detection limit (IDL).

4.1 Sediment Results

One hundred seventy-two composite sediment samples and 58 grab sediment samples were collected during Phase I and II of the Soldier Creek RI, as described in Subsections 2.2.1 and 2.3.1. Composite sediment samples were collected from 0-6 and 6-12 inches during Phase I of the RI, and 0-1, 1-2, 2-3, 3-4, and 4-5 foot intervals during Phase II of the RI. The composite sediment samples were analyzed for semi-volatile organics on the TCL, and metals including cyanide on the TAL, in Phase I of the RI; semi-volatiles and metals (antimony, cadmium, chromium, lead) including cyanide were analyzed during Phase II of the RI. The composite sediment samples were analyzed for SAS physical parameters in Phase I and II of the RI, including Atterberg limits, grain particle size distribution, total organic carbon, and density. The TCLP analysis was performed only on composite sediment samples collected from the 0-1 and 1-2 foot intervals because adequate soil volumes could not be collected from the deeper intervals. The discrete grab sediment samples were analyzed for volatile organics on the TCL during Phase I and II of the RI. Sediment analytical results for compounds detected above the detection limit are presented on Figures 4-1 through 4-3, and 4-7 through 4-9 in Volume 2 of the RI report. The complete sediment analytical data, including all non-detected compounds, are presented in Tables B-1 through B-69 (pages B-1 through B-82) of Appendix B (Volume 3). Phase I and II sampling locations are illustrated on Figures 2-1 and 2-2 (pages 2-5 and 2-11), respectively. Analytical results with an "ND" designation indicate analyte concentrations below the IDL.

4.1.1 Sediment Volatile Organic Results

The Phase I and II sediment volatile organic analytical results include methylene chloride, acetone, 1,2-dichloroethene (total), chloroform, trichloroethene, benzene, carbon disulfide, tetrachloroethene, toluene, chlorobenzene, chloroethane, ethylbenzene, vinyl acetate and xylene (total). These chemicals of potential concern are identified in the Risk Assessment report (BVWST, 1993a), shown on Table 4-1 (page 4-3), and will be discussed in this subsection. A summary of the volatile organics detected in the sediment samples is shown in Table 4-2 (pages 4-4 through 4-9). The sediment volatile organic analytical results are presented on Figures 4-1 and 4-7 in Volume 2 of the RI report, and Tables B-1 (pages B-2 and B-3), B-4 (pages B-10 through B-12), and B-7 through B-23 (pages B-20 through B-36) of Appendix B (Volume 3).

4.1.1.1 Sediment Volatile Organic Results for Background Locations. Four sediment background samples were collected at off-base locations C01, C02, C03, and D01 during the Phase II RI, as illustrated on Figure 2-2 (page 2-11). Only background location C01 was sampled during both Phase I and II of the RI.

The Phase I sediment analytical results for location C01 detected concentrations of methylene chloride [10.0 micrograms per kilogram (ug/kg)] and chloroform (5.0 ug/kg) at the 0-6 inch interval and acetone (9.0 ug/kg) at the 6-12 inch interval.

The Phase II sediment analytical results for location C01 detected concentrations of methylene chloride, acetone, chloroform, toluene, and xylene (total). Methylene chloride was detected in the 0-1 foot interval (26.0 ug/kg), 1-2 foot interval (1.0 ug/kg), and 4-5 foot interval (2.0 ug/kg). Acetone was detected in the 0-1 foot interval (44.0 ug/kg), 1-2 foot interval (8.0 ug/kg), and 4-5 foot interval (12.0 ug/kg). Chloroform was detected in the 1-2 foot interval (2.0 ug/kg), 2-3 foot interval (1.0 ug/kg), and 3-4 foot interval (1.0 ug/kg). Toluene was detected in the 1-2 foot interval (2.0 ug/kg). Xylene (total) was detected in the 1-2 foot interval (1.0 ug/kg), 2-3 foot interval (1.0 ug/kg), 3-4 foot interval (1.0 ug/kg), and 4-5 foot interval (2.0 ug/kg).

TABLE 4-1
SURFACE WATER AND SEDIMENT CHEMICALS OF POTENTIAL CONCERN
TINKER AFB – SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

SURFACE WATER		
VOLATILES	SEMI-VOLATILES	METALS
Acetone	Benzo(G,H,I)perylene	Aluminum
Benzene	Benzoic Acid	Arsenic
Bromodichloromethane	Chrysene	Barium
Bromoform	Fluoranthene	Beryllium
Carbon Disulfide	Pyrene	Cadmium
Chlorobenzene		Calcium
Chloroform		Chromium
Dibromochloromethane		Cobalt
1,2-Dichloroethene (total)		Copper
Methylene Chloride		Cyanide
Tetrachloroethene		Iron
Toluene		Lead
1,1,1-Trichloroethane		Magnesium
Trichloroethene		Manganese
Xylene (total)		Nickel
		Potassium
		Selenium
		Silver
		Sodium
		Vanadium
		Zinc

SEDIMENT		
VOLATILES	SEMI-VOLATILES	METALS
Acetone	2-Methylphenol	Aluminum
Benzene	4-Methylphenol	Arsenic
Carbon Disulfide	2,4-Dimethylphenol	Barium
Chlorobenzene	Acenaphthene	Cadmium
Chloroethane	Anthracene	Calcium
Chloroform	Benzo(A)anthracene	Chromium
1,2-Dichloroethene (Total)	Benzo(B)fluoranthene	Cobalt
Ethylbenzene	Benzo(K)fluoranthene	Copper
Methylene Chloride	Benzo(G,H,I)perylene	Cyanide
Tetrachloroethene	Benzo(A)pyrene	Iron
Toluene	Bis(2-ethylhexyl)phthalate	Lead
Trichloroethene	Butylbenzylphthalate	Magnesium
Vinyl Acetate	2-Chloronaphthalene	Manganese
Xylene (total)	Chrysene	Mercury
	Dibenz(A,H)anthracene	Nickel
	Dibenzofuran	Potassium
	1,2-Dichlorobenzene	Selenium
	1,3-Dichlorobenzene	Silver
	1,4-Dichlorobenzene	Vanadium
	3-3'-Dichlorobenzidine	Zinc
	Di-n-butylphthalate	
	Di-n-octylphthalate	
	Fluoranthene	
	Fluorene	
	Indeno(1,2,3-CD)pyrene	
	Naphthalene	
	2-Methylnaphthalene	
	Phenanthrene	
	Pyrene	

TABLE 4-2
SEDIMENT VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB – SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Methylene Chloride IDL = 0.37 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	1/1	C01	9.0 to 10.0	C01 (0-6 inch interval)	Paint remover, solvent degreasing, plastics processing, blowing agent in foams, solvent extraction, solvent in cellulose acetate, aerosol propellant.
	Phase II	3/4	C01, C02, C03	ND to 30.0	C02 (0-1 foot interval)	
	Phase I	13/13	All Locations	ND to 37.0	M05 (6-12 inch interval)	
	Phase II	3/3	All Locations	ND to 30.0	M07 (2-3 foot interval)	
	Phase I	13/13	All Locations	ND to 140,000.0	E03 (0-6 inch interval)	
	Phase II	4/5	E06, E11, E12, E13	ND to 51.0	E11 (1-2 foot interval)	
	Phase I	8/8	All Locations	ND to 140.0	W03 (6-12 inch interval)	
Acetone IDL = 0.69 ug/l (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase II	2/5	W06, W07	ND to 6.0	W06 (0-1 foot interval)	Paint, varnish, and lacquer solvent; cellulose acetate, especially as spinning solvent; to clean and dry parts of precision equipment; solvent for potassium iodide and permanganate; delusterant for cellulose acetate fibers; specification testing of vulcanized rubber products.
	Phase I	6/6	All Locations	ND to 100.0	B02 (0-6 inch interval)	
	Phase I	1/1	C01	ND to 9.0	C01 (6-12 inch interval)	
	Phase II	4/4	C01, C02, C03, D01	ND to 51.0	D01 (3-4 foot interval)	
	Phase I	9/13	M01, M02, M05, M06, M07 M08, M11, M12, M13	ND to 290.0	M06 (0-6 inch interval)	
	Phase II	2/3	M07, M08	ND to 37.0	M07 (2-3 foot interval)	
	Phase I	12/13	E01, E02, E04, E05, E06, E07, E08 E09, E10, E11, E12, E13	ND to 290.0	E09 (6-12 inch interval)	
	Phase II	4/5	E06, E11, E12, E13	ND to 51.0	E12 (3-4 foot interval)	
	Phase I	6/8	W01, W02, W03, W04, W06, W08 W04, W06, W07	ND to 420.0	W04 (6-12 inch interval)	
	Phase II	3/5	A01, B01, B02, B03	ND to 38.0	W06 (0-1 foot interval)	
1,2-Dichloroethene (Total) IDL = 0.41 ug/l (1) East Soldier Creek	Phase I	4/6		ND to 1,700.0	B02 (0-6 inch interval)	General solvent for organic materials, dye extraction, perfumes, lacquers, thermoplastics, organic synthesis.
	Phase II	2/13 0/5	E03, E06 ND	ND to 180,000.0 ND	E03 (0-6 inch interval) ND	

TABLE 4-2 (CONTINUED)
 SEDIMENT VOLATILE ORGANIC ANALYTICAL SUMMARY
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Chloroform IDL = 0.78 ug/L (1) Background	Phase I	1/1	C01	5.0	C01 (0-6, 6-12 inch intervals)	Fluorocarbon, plastics, solvent, analytical chemistry, fumigant, insecticides.
	Phase II	3/4	C01, C02, D01	ND to 2.0	C01 (1-2 foot interval) C02 (3-4 foot interval) D01 (0-1 foot interval)	
	Phase I	13/13	All Locations	4.0 to 32.0	M06 (0-6 inch interval)	
	Phase II	1/3	M07	ND to 0.6	M07 (1-2 foot interval)	
	Phase I	13/13	All Locations	ND to 9,200.0	E03 (0-6 inch interval)	
	Phase II	0/5	ND	ND	ND	
Main Soldier Creek	Phase I	8/8	All Locations	3.0 to 45.0	W04 (6-12 inch interval)	Metal degreasing; extraction solvent for oils, fats, waxes; solvent dyeing; dry cleaning; refrigerant and heat exchange liquid; fumigant; cleaning and drying electronic parts; diluent in paints and adhesives; textile processing; chemical intermediate; aerospace operations (flushing liquid oxygen).
	Phase I	1/5	W07	ND to 2.0	W07 (2-3, 3-4, 4-5 foot intervals)	
	Phase II	6/6	All Locations	4.0 to 28.0	B02 (0-6 inch interval)	
	Phase I					
East Soldier Creek	Phase I	1/13	E03	ND to 4,100.0	E03 (0-6 inch interval)	
	Phase II	0/5	ND	ND	ND	
West Soldier Creek						
Tributary A and B						
Trichloroethene IDL = 0.54 ug/L (1) East Soldier Creek	Phase I	1/13	E03	ND to 4,100.0	E03 (0-6 inch interval)	Metal degreasing; extraction solvent for oils, fats, waxes; solvent dyeing; dry cleaning; refrigerant and heat exchange liquid; fumigant; cleaning and drying electronic parts; diluent in paints and adhesives; textile processing; chemical intermediate; aerospace operations (flushing liquid oxygen).
	Phase II	0/5	ND	ND	ND	

TABLE 4-2 (CONTINUED)
 SEDIMENT VOLATILE ORGANIC ANALYTICAL SUMMARY
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Benzene IDL = 0.33 ug/L (1) Main Soldier Creek	Phase I Phase II	0/13 1/3	ND M09	ND ND to 1.0	ND M09 (0-1 foot interval)	Manufacturing of ethylbenzene (for styrene monomer); dodecylbenzene (for detergents); cyclohexane (for nylon); phenol; nitrobenzene (for aniline); maleic anhydride; chlorobenzene; diphenyl; benzene hexachloride; benzene-sulfonic acid; as a solvent.
Carbon Disulfide IDL = 0.43 ug/L (1) West Soldier Creek East Soldier Creek	Phase I Phase II Phase I Phase II	1/8 1/5 0/13 1/5	W06 W07 ND E11	ND to 36.0 ND to 0.9 ND ND to 2.0	W06 (0-6 inch interval) W07 (2-3 foot interval) ND E11 (0-1 foot interval)	Viscose rayon, cellophane, manufacture of carbon tetrachloride and flotation agents, solvent.
Tetrachloroethene IDL = 0.35 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I Phase II Phase I Phase II Phase I Phase II Phase I Phase II	0/1 2/4 0/13 1/3 2/13 0/5 0/8 2/5	ND C02, C03 ND M07 E02, E03 ND ND W04, W07	ND ND to 11.0 ND ND to 2.0 ND to 83,000.0 ND ND ND to 5.0	ND C02 (3-4 foot interval) ND M07 (1-2 foot interval) E03 (0-6 inch interval) ND ND W04 (1-2 foot interval)	Dry cleaning solvent, vapor degreasing solvent, drying agent for metals and certain other solids, vermifuge heat-transfer medium, manufacture of fluorocarbon.

TABLE 4-2 (CONTINUED)
SEDIMENT VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Toluene IDL = 0.85 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	0/1	ND	ND	ND	Aviation gasoline and high octane blending stock; benzene, phenol, and caprolactam; solvent for paints and coatings, gums, resins, most oils, rubber, vinyl organosols; diluent and thinner in nitrocellulose lacquers; adhesive solvent in plastic toys and model airplanes; chemical (benzoic acid, benzyl and benzoyl derivatives, saccharin, medicines dyes, perfumes); source of toluene diisocyanates (polyurethane resins); explosives; toluene sulfonates (detergents); scintillation counters.
	Phase II	2/4	C01, C02	ND to 6.0	C02 (1-2 foot interval)	
	Phase I	3/13	M10, M11, M13	ND to 12.0	M11 (6-12 inch interval)	
	Phase II	2/3	M07, M08	ND to 3.0	M13 (0-6 inch interval)	
	Phase I	4/13	E03, E05, E06, E08	ND to 980.0	M07 (1-2 foot interval)	
	Phase II	0/5	ND	ND	E03 (6-12 inch interval)	
	Phase I	3/8	W01, W02, W03	ND to 620.0	ND	
Chlorobenzene IDL = 0.87 ug/L (1) Main Soldier Creek East Soldier Creek	Phase II	0/5	ND	ND	ND	Phenol, chloronitrobenzene, aniline, solvent carrier for methylene diisocyanate, solvent, pesticide intermediate, heat transfer.
	Phase I	2/6	B01, B03	ND to 2.0	W02 (6-12 inch interval)	
					B01 (0-6 inch interval)	
					B03 (6-12 inch interval)	
	Phase I	1/13	M12	ND to 8.0	M12 (6-12 inch interval)	
	Phase II	0/3	ND	ND	ND	
	Phase I	3/13	E03, E08, E10	ND to 78,000.0	E03 (0-6 inch interval)	
	Phase II	1/5	E06	ND to 10.0	E06 (0-1 foot interval)	

TABLE 4-2 (CONTINUED)
 SEDIMENT VOLATILE ORGANIC ANALYTICAL SUMMARY
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Chloroethane IDL = 0.19 ug/L (1) East Soldier Creek West Soldier Creek	Phase I Phase II Phase I Phase II	1/13 0/5 0/8 0/5	E06 ND ND ND	ND to 86.0 ND ND ND	E06 (0-6 inch interval) ND ND ND	Manufacture of tetraethyl lead and ethylcellulose; anesthetic; organic synthesis; alkylating agent; refrigeration; analytical reagent; solvent for phosphorus, sulfur, fats, oils, resins, and waxes; insecticides.
Ethylbenzene IDL = 0.79 ug/L (1) West Soldier Creek	Phase I Phase II	1/8 0/5	W03 ND	ND to 4.0 ND	W03 (0-6 inch interval) ND	Intermediate in production of styrene, solvent.
Vinyl Acetate IDL = 0.77 ug/L (1) East Soldier Creek	Phase I Phase II	1/13 0/5	E11 ND	ND to 0.9 ND	E11 (0-6 inch interval) ND	Polyvinyl acetate, polyvinyl alcohol, polyvinyl butyral, and polyvinyl chloride-acetate resins, used particularly in latex paints, paper coating, adhesives, textile finishing, safety glass interlayers.

TABLE 4-2 (CONTINUED)
SEDIMENT VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Xylene (Total) IDL = 0.55 ug/L (1) Background	Phase I	0/1	ND	ND	ND	Aviation gasoline; protective coatings; solvent for alkyd resins, lacquers, enamels, rubber cements; synthesis of organic chemicals.
	Phase II	2/4	C01, C02	ND to 6.0	C02 (4-5 foot depth)	
Main Soldier Creek	Phase I	0/13	ND	ND	ND	
	Phase II	2/3	M07, M09	ND to 6.0	M07 (1-2 foot interval)	
East Soldier Creek	Phase I	2/13	E02, E06	ND to 1,000.0	E06 (0-6 inch interval)	
	Phase II	2/5	E06, E12	ND to 1.0	E06 (0-1 and 1-2 foot intervals) and E12 (2-3 foot interval)	
West Soldier Creek	Phase I	1/8	W03	ND to 69.0	W03 (6-12 inch interval)	
	Phase II	1/5	W07	ND to 2.0	W07 (1-2 foot interval)	

Legend:

IDL - Instrument Detection Limit.

ND - Not Detected.

Notes:

- (1) The IDL of an individual sediment sample varies with moisture content, therefore no direct comparison can be made between the extract and the sediment sample concentration.
- (2) Frequency of detection refers to the number of locations an analyte was detected versus the total number of locations sampled on that segment.

The analytical results for location C02 detected concentrations of methylene chloride, acetone, chloroform, tetrachloroethene, toluene, and xylene (total). Methylene chloride was detected in three depths ranging from not detected to 30.0 ug/kg (0-1 foot interval). Acetone was detected only in the 0-1 foot interval with a concentration of 47.0 ug/kg. Chloroform was detected in three depths with a maximum concentration of 2.0 ug/kg in the 3-4 foot interval. Tetrachloroethene was detected in four of the five depths, with concentrations ranging from not detected to 11.0 ug/kg (3-4 foot interval). Toluene was detected in four of the five depths, with concentrations ranging from not detected to 6.0 ug/kg (1-2 foot interval). Xylene (total) was detected in four of the five depths, with concentrations ranging from not detected to 6.0 ug/kg (4-5 foot depth).

The analytical results for location C03 detected concentrations of methylene chloride, acetone, and tetrachloroethene. Methylene chloride was detected at all depths ranging from 3.0 ug/kg (0-1 foot interval) to 5.0 ug/kg (3-4 and 4-5 foot intervals). Acetone was detected in only the 0-1 foot interval at a concentration of 16.0 ug/kg. Tetrachloroethene was detected only in the 1-2 foot interval at a concentration of 2.0 ug/kg.

The analytical results for location D01 detected the presence of acetone and chloroform. Acetone was detected in the 3-4 foot interval (51.0 ug/kg) and 4-5 foot interval (3.0 ug/kg). Chloroform was detected only in the 0-1 foot interval at a concentration of 2.0 ug/kg.

4.1.1.2 Sediment Volatile Organic Results for Main Soldier Creek Locations.

Thirteen locations along Main Soldier Creek were investigated during Phase I of the RI. The sediment volatile organic analytical results for these thirteen locations detected concentrations of methylene chloride, acetone, chloroform, toluene, and chlorobenzene. Methylene chloride was detected at all thirteen locations with concentrations ranging from not detected to 25.0 ug/kg (M08, 0-6 inch interval). Acetone was detected at nine (M01, M02, M05, M06, M07, M08, M11, M12, M13) of the thirteen locations with concentrations ranging from not detected to 290.0 ug/kg (M06, 0-6 inch interval). Chloroform was detected at all thirteen locations with concentrations ranging from 5.0 ug/kg to 32.0 ug/kg (M06, 0-6 inch interval). Toluene was detected at three (M10, M11, M13) of the thirteen locations with concentrations

ranging from not detected to 12.0 ug/kg (M13, 0-6 inch interval). Chlorobenzene was detected only at location M12 at a concentration of 8.0 ug/kg (6-12 inch interval). Methylene chloride, acetone, and toluene, are common laboratory contaminants. Because the methylene chloride and toluene concentrations do not exceed ten times the limit CRQL, it is probable that these concentrations are due to laboratory cross-contamination. The low concentration of chlorobenzene detected at a single location and depth interval appears to be an anomaly in the data set.

Three locations (M07, M08, M09) along Main Soldier Creek were investigated during Phase II of this RI. These locations were investigated in Phase II of the RI due to the relatively high levels of the chemicals of potential concern detected during Phase I of the RI. The Phase II sediment volatile organic analytical results for these three locations show the presence of methylene chloride, acetone, chloroform, toluene, benzene, tetrachloroethene, and xylene (total). Methylene chloride was detected at all three locations with analytical results ranging from not detected to 30.0 ug/kg (M07, 2-3 foot interval). Acetone was detected at locations M07 and M08, and ranged from not detected to 37.0 ug/kg (M07, 2-3 foot interval). Chloroform was detected only at location M07 (0.6 ug/kg) in the 1-2 foot interval. Toluene was detected only at location M07 (3.0 ug/kg) in the 1-2 foot interval. Trace concentrations of benzene (1.0 ug/kg) and xylene (total) (1.0 ug/kg) were detected at location M09 in the 0-1 foot interval. Xylene (total) was also detected at location M09 at a concentration of 6.0 ug/kg (1-2 foot interval). A trace concentration (2.0 ug/kg) of tetrachloroethene was detected at location M07 (1-2 foot interval). These results are similar to Phase I data on-base. It appears that the methylene chloride, acetone, and toluene are a result of laboratory cross-contamination. Building 3001 outfalls have been identified as a source of chloroform, benzene, tetrachloroethene, toluene, and xylene (total) contamination (NUS, 1989). While locations M07, M08, and M09 are downstream of Building 3001 outfalls, these locations are almost one mile downstream of the Building 3001 outfalls and receive surface runoff from the surrounding area located off-base from Tinker AFB. These facts, taken together with the low concentrations of these contaminants, make it impossible to conclusively identify sources of contamination at these locations and to conclusively state whether off-base migration is the source of contamination at these locations.

4.1.1.3 Sediment Volatile Organic Results for East Soldier Creek Locations.

Thirteen locations were investigated during Phase I of the RI along East Soldier Creek. The sediment volatile organic analytical results detected the presence of methylene chloride, acetone, 1,2-dichloroethene (total), chloroform, trichloroethene, tetrachloroethene, toluene, chlorobenzene, chloroethane, vinyl acetate, and xylene (total). Methylene chloride was detected at all East Soldier Creek Phase I locations at either the 0-6 inch interval or the 6-12 inch interval, at concentrations ranging from not detected to 140,000 ug/kg (E03, 0-6 inch interval). Acetone was detected at all Phase I locations, except E03, with concentrations ranging from not detected to 290.0 ug/kg (E09, 6-12 inch interval). 1,2-Dichloroethene (total) was detected at two (E03, E06) of the thirteen locations with concentrations ranging from not detected to 180,000 ug/kg (E03, 0-6 inch interval). Chloroform was detected at all thirteen locations, ranging from not detected to 9,200 ug/kg (E03, 0-6 inch interval). Trichloroethene was detected only at location E03 (0-6 inch interval) at a concentration of 4,100 ug/kg. Tetrachloroethene was detected at location E02 (0-6 inch interval) with a concentration of 2.0 ug/kg and location E03 (0-6 and 6-12 inch intervals) with concentrations of 83,000 ug/kg and 2,700 ug/kg, respectively. Toluene was detected at four (E03, E05, E06, E08) of the thirteen locations ranging from not detected to 980.0 ug/kg (E03, 6-12 inch interval). Chlorobenzene was detected at three (E03, E08, E10) of the thirteen locations, with concentrations ranging from not detected to 78,000 ug/kg (E03, 0-6 inch interval). Chloroethane was detected only at location E06 with a concentration of 86.0 ug/kg (0-6 inch interval). Vinyl acetate was detected only at location E11 with a concentration of 0.9 ug/kg (0-6 inch interval). Xylene (total) was detected at two of the thirteen locations (E02, E06) at concentrations ranging from not detected to 1,000 ug/kg (E06, 0-6 inch interval). Samples from location E03 (an on-base location) contained relatively high concentrations of acetone, 1,2-dichloroethene (total), chloroform, trichloroethene, tetrachloroethene, toluene, and chlorobenzene when compared to other East Soldier Creek sampling locations. The high concentrations of volatile organics are on-base and downstream of outfall G (shown on Figure 4-1, Volume 2) that had been documented to discharge volatile organics into East Soldier Creek (NUS, 1989). The off-base sampling locations along East Soldier Creek had lower chemical concentrations than on-base sampling locations. There also appears to be a general trend for higher volatile organic concentrations to be found in the 6-12 inch interval, likely due to the high mobility of volatile organics in the Soldier Creek sediments.

It is unlikely that volatile organics would be present at deeper intervals based on the clayey geology that retards contaminant migration.

Five locations (E03, E06, E11, E12, E13) were investigated during Phase II of the RI along East Soldier Creek. These locations were further investigated due to the relatively high levels of chemicals of potential concern detected during the Phase I investigation. At sample location E03, sediment samples were only collected at the 1-2 foot interval and not at the 0-1 foot interval. When the split spoon sampler was driven into the sediment at location E03 organic material from the decay of vegetation and existing plant vegetation at this depth was encountered. Upon removal of the split spoon from location E03, only decayed vegetation was present; therefore, the sample was not sent for analysis. The Phase II volatile organic analytical data for the other four locations detected the presence of methylene chloride, acetone, carbon disulfide, chlorobenzene, and xylene (total). Methylene chloride was detected at four (E06, E11, E12, E13) of the five locations, ranging from not detected to 51.0 ug/kg (E11, 1-2 foot interval). Acetone was detected at all locations, except E03, ranging from below detection levels to 51.0 ug/kg (E12, 3-4 foot interval). A trace amount (2.0 ug/kg) of carbon disulfide was detected in the duplicate of the 0-1 foot interval sample at location E11. Chlorobenzene (10.0 ug/kg) was detected only at location E06, 0-1 foot interval. Xylene (total) was detected only at location E06 (0-1 and 1-2 foot intervals) at a concentration of 1.0 ug/kg. The Phase II analytical results are similar to the Phase I analytical results. The source of methylene chloride is unknown. Based on the concentration ranges of methylene chloride and acetone these contaminants appear to be from laboratory cross-contamination. The concentrations of carbon disulfide and chlorobenzene were the only detections within the analytical data set. Chlorobenzene and carbon disulfide use at Tinker AFB has not been documented, therefore, these concentrations appear to be an anomaly from the general trend illustrated in the analytical data set. The usage of xylene (total) in Building 3001 has been identified in the Building 3001 RI (Tulsa COE, 1988a); therefore, Building 3001 may be a source of xylene (total) contamination. No general trends concerning the location or concentration of volatile organics with depth were observed. The Phase II analytical results indicate lower concentrations of volatile organics than the Phase I analytical results along on-base portions of East Soldier Creek.

4.1.1.4 Sediment Volatile Organic Results for West Soldier Creek Locations.

Eight locations were investigated during Phase I of the RI along West Soldier Creek. The sediment volatile organic analytical results for these eight locations detected the presence of methylene chloride, acetone, carbon disulfide, chloroform, ethylbenzene, toluene, and xylene (total). Methylene chloride was detected at all locations, ranging from not detected to 140.0 ug/kg (W03, 6-12 inch interval). Acetone was detected at six (W01, W02, W03, W04, W06, W08) of the eight locations, ranging from below detection levels to 420.0 ug/kg (W04, 6-12 inch interval). Carbon disulfide was detected only at location W06 with a concentration of 36.0 ug/kg (0-6 inch interval). Chloroform was detected at all locations, ranging from 3.0 ug/kg (W06, 0-6 inch interval) to 45.0 ug/kg (W04, 6-12 inch interval). Ethylbenzene was detected only at location W03 (0-6 inch interval) at a concentration of 4.0 ug/kg. Toluene was detected at three (W01, W02, W03) of the eight locations, ranging from not detected to 620.0 ug/kg (W02, 6-12 inch interval). Xylene (total) was detected only at location W03 (6-12 inch interval) at a concentration of 69.0 ug/kg. Xylene (total) and toluene are commonly used as aviation gasoline and are common solvents used in cleaning aviation parts. It is possible that the concentrations of these contaminants are due to surface runoff from inadvertent spills of airline fuel along runway which is directly adjacent to West Soldier Creek. Based on the Phase I volatile organic analytical results, concentrations were detected only in on-base locations. There also appears to be a general trend for higher volatile organic concentrations in the 6-12 inch interval, likely due to the high mobility of volatile organics within the sediments. It is unlikely that volatile organics would be present at deeper intervals based on the clayey geology that retards contaminant migration.

Five locations (W03, W04, W06, W07, W08) were investigated during Phase II of the RI along West Soldier Creek. These locations were further investigated due to the relatively high concentrations of chemicals of potential concern detected during the Phase I investigation. The Phase II volatile organic analytical data for these five locations detected methylene chloride, acetone, chloroform, carbon disulfide, tetrachloroethene, and xylene (total). Methylene chloride was detected only at locations W06 and W07, with concentrations ranging from not detected to 6.0 ug/kg (W06, 0-1 foot interval). Acetone was detected at three (W04, W06, W07) of the five locations, ranging from below detection levels to 38.0 ug/kg (W06, 0-1 foot interval). Chloroform was detected only at location W07 (2-3, 3-4, and 4-5 foot intervals) at a

concentration of 2.0 ug/kg for each interval. A trace amount (0.9 ug/kg) of carbon disulfide was detected in the 2-3 foot interval at location W07. Tetrachloroethene and xylene (total) were detected in the 1-2 foot interval at locations W04 (5.0 ug/kg) and W07 (2.0 ug/kg), respectively. Because the concentrations of methylene chloride, and acetone, do not exceed ten times the CRQL, it is possible that these concentrations are due to laboratory cross-contamination. The Phase II analytical results indicate only relatively low volatile organic concentrations of carbon disulfide, tetrachloroethene, and xylene (total). The usage of xylene (total) in Building 3001 has been identified in the Building 3001 RI (Tulsa COE, 1988a); therefore, Building 3001 may be a source of xylene (total) contamination. While it is true that tetrachloroethene and xylene (total) were detected in either Phase I or II samples collected from on-base locations W03 and W04, location W07 is located almost one mile downstream of these points. Location W07 does receive runoff from the surrounding area located off-base from Tinker AFB. In addition, location W06 samples did not contain any detected concentrations of tetrachloroethene or xylene during either phase of the investigation. These facts, taken together with the low concentrations of these contaminants, make it impossible to conclusively identify sources of contamination at this location and to conclusively state whether off-base migration has occurred.

4.1.1.5 Sediment Volatile Organic Results for A and B Tributary Locations.

Six locations were investigated during Phase I of the RI along Tributaries A and B of Main Soldier Creek. The sediment volatile organic analytical results for these six locations detected the presence of methylene chloride, acetone, chloroform, and toluene. Methylene chloride was detected at all locations, ranging from not detected to 100.0 ug/kg (B02, 0-6 inch interval). Acetone was detected at four (A01, B01, B02, B03) of the six locations ranging from not detected to 1,700 ug/kg (B02, 0-6 inch interval). Chloroform was detected at all locations, ranging from 4.0 ug/kg (B03, 0-6 inch and 6-12 inch intervals) to 28.0 ug/kg (B02, 0-6 inch interval). Only trace concentrations (2.0 ug/kg each) of toluene were detected at locations B01 (0-6 inch interval) and B03 (6-12 inch interval). Toluene is a common laboratory contaminant. Because the concentration of toluene does not exceed ten times the CRQL, it is possible that the toluene concentration is due to laboratory cross-contamination. No general trends in the Phase I RI analytical data for Tributaries A and B were detected. No locations along the tributaries were investigated during Phase II of the

RI due to the relatively low concentrations of the chemicals of concern detected during the Phase I investigation.

4.1.2 Sediment Semi-Volatile Organic Results

The Phase I and II sediment semi-volatile organic analytical results include 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, 2-methylphenol, 4-methylphenol, 2,4-dimethylphenol, naphthalene, 2-methylnaphthalene, 2-chloronaphthalene, acenaphthene, dibenzofuran, fluorene, phenanthrene, anthracene, di-n-butylphthalate, fluoranthene, pyrene, butylbenzylphthalate, 3,3-dichlorobenzidine, benzo(a)anthracene, chrysene, bis(2-ethylhexyl)phthalate, di-n-octylphthalate, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene, which are chemicals of potential concern identified in the Risk Assessment report (BVWST, 1993a). The sediment samples collected in Phase II of the RI were analyzed for semi-volatile organic compounds only at location W04. A summary of the detected sediment semi-volatile organic analytical results is shown in Table 4-3 (pages 4-17 through 4-22). The sediment semi-volatile organic analytical results are presented on Figures 4-2 and 4-8 in Volume 2 of the RI report, and in Tables B-2 (pages B-4 through B-7), B-5 (pages B-13 through B-16), and B-24 (page B-37) of Appendix B (Volume 3).

4.1.2.1 Sediment Semi-Volatile Organic Results for Background Locations.

One background sediment sample (C01) was collected off-base during Phase I of the RI. Bis(2-ethylhexyl)phthalate was the only contaminant detected by Phase I of the RI sediment semi-volatile analytical results at a concentration of 120.0 ug/kg (0-6 inch interval). The background sediment samples collected from locations C01, C02, C03, and D01 were not analyzed for semi-volatile organics during the Phase II RI due to the relatively low concentrations of chemicals of potential concern detected at location C01 during the Phase I RI.

4.1.2.2 Sediment Semi-Volatile Organic Results for Main Soldier Creek Locations. Thirteen locations were investigated during Phase I of the RI along Main Soldier Creek. The sediment semi-volatile organic analytical results for these

TAL 4-3
SEDIMENT SEMI-VOLATILE ORGANIC ANALYTICAL SUMMARY
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ANALYTE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
1,4-Dichlorobenzene IDL = 4.58 ug/L (1) East Soldier Creek West Soldier Creek	4/13 1/8	E03, E08, E09, E10 W04	ND to 4,400.0 ND to 2,200.0	E03 (6-12 inch interval) W04 (0-6 inch interval)	Moth repellent, general insecticide, germicide, space odorant manufacture of 2,5-dichloroaniline, dyes, intermediates, pharmacy, agriculture (fumigating soil).
1,2-Dichlorobenzene IDL = 5.75 ug/L (1) East Soldier Creek West Soldier Creek	3/13 1/8	E03, E09, E10 W04	ND to 3,100.0 ND to 220.0	E03 (6-12 inch interval) W04 (0-6 inch interval)	Manufacture of 3,4-dichloroaniline, solvent for a wide range of organic materials and for oxides of nonferrous metals, solvent carrier in production of voluene diisocyanate, dye manufacture, fumigant and insecticide, degreasing hides and wool, metal polishes, industrial odor control, heat transfer.
1,3-Dichlorobenzene IDL = 4.71 ug/L (1) East Soldier Creek West Soldier Creek	3/13 1/8	E03, E09, E10 W04	ND to 280.0 ND to 210.0	E03 (6-12 inch interval) W04 (0-6 inch interval)	Moth repellent, general insecticide, germicide, space odorant manufacture of 2,5-dichloroaniline, dyes, intermediates, pharmacy, agriculture (fumigating soil).
2-Methylphenol IDL = 4.60 ug/L (1) East Soldier Creek	1/13	E09	ND to 68.0	E09 (6-12 inch interval)	Disinfectant, phenolic resins, tricresyl phosphate, ore flotation, textile scouring agent, organic intermediate, manufacture of salicylaldehyde, coumarin, and herbicides, surfactant, synthetic food flavors (para isomer only).

TABLE 4-3 (CONTINUED)
SEDIMENT SEMI-VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
4-Methylphenol IDL = 4.60 ug/L (1) East Soldier Creek	1/13	E09	ND to 98.0	E09 (6-12 inch interval)	Disinfectant, phenolic resins, tricresyl phosphate, ore flotation, textile scouring agent, organic intermediate, manufacture of salicylaldehyde, coumarin, and herbicides, surfactant, synthetic food flavors (para isomer only).
Naphthalene IDL = 16.24 ug/L (1) East Soldier Creek West Soldier Creek	7/13 4/8	E01, E03, E04, E07, E08, E09, E10 W03, W06, W07, W08	ND to 600.0 ND to 690.0	E09 (6-12 inch interval) W03 (0-6 inch interval)	Intermediate (phthalic anhydride, naphthal, "Tertralin," "Decaline," chlorinated naphthalene).
2-Methylnaphthalene IDL = 5.44 ug/L (1) East Soldier Creek West Soldier Creek	6/13 4/8	E01, E03, E07, E08, E09, E10 W03, W06, W07, W08	ND to 1,900.0 ND to 1,300.0	E03 (6-12 inch interval) W08 (0-6 inch interval)	Organic synthesis.
2-Chloronaphthalene IDL = 9.44 ug/L (1) East Soldier Creek	4/13	E07, E08, E09, E10	ND to 1,600.0	E08 (0-6 inch interval)	Solvent, immersion liquid in microscopy.
Acenaphthene IDL = 4.22 ug/L (1) East Soldier Creek West Soldier Creek	8/13 4/8	E01, E02, E04, E06, E07, E08, E09, E10 W03, W06, W07, W08	ND to 250.0 ND to 1,100.0	E04 (0-6 inch interval) W03 (0-6 inch interval)	Dye intermediate; pharmaceuticals; insecticide; fungicide; plastics.

TABLE 4-3 (CONTINUED)
SEDIMENT SEMI-VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Dibenzofuran IDL = 3.14 ug/L (1) East Soldier Creek	6/13	E01, E02, E03, E04, E07, E10	ND to 340.0	E03 (0-6 inch interval)	Insecticide.
West Soldier Creek	1/8	W03	ND to 480.0	W03 (0-6 inch interval)	
Fluorene IDL = 1.91 ug/L (1) East Soldier Creek	5/13	E01, E02, E07, E09, E10	ND to 200.0	E09 (6-12 inch interval)	Resinous products, dye stuffs.
West Soldier Creek	4/8	W03, W06, W07, W08	ND to 880.0	W03 (0-6 inch interval)	
Phenanthrene IDL = 3.42 ug/L (1) East Soldier Creek	11/13	E01, E02, E03, E04, E05, E06, E07, E08, E09, E10, E11	ND to 6,700.0	E03 (0-6 inch interval)	Dyestuffs, explosives, synthesis of drugs, biochemical research, manufacturing, phenanthraquinone.
West Soldier Creek	7/8	W01, W02, W03, W04, W06, W07, W08	ND to 6,000.0	W03 (0-6 inch interval)	
Tributary A and B	2/6	B01, B03	ND to 73.0	B03 (6-12 inch interval)	
Anthracene IDL = 1.43 ug/L (1) East Soldier Creek	9/13	E01, E02, E03, E04, E06, E07, E08, E09, E10	ND to 1,500.0	E03 (0-6 inch interval)	Dyes, alizarin, phenanthrene, carbazole, anthraquinone, calico printing, a component of smoke screens, crystals, scintillation counting, organic semi-conductor research.
West Soldier Creek	7/8	W01, W02, W03, W04, W06, W07, W08	ND to 1,000.0	W03 (0-6 inch interval)	
Tributary A and B	1/6	B03	ND to 10.0	B03 (0-6 inch interval)	
Di-n-butylphthalate IDL = 4.02 ug/L (1) Main Soldier Creek	3/13	M05, M06, M07	ND to 30.0	M07 (0-6 inch interval)	Plasticizer in nitrocellulose lacquers, elastomers, explosives, nail polish and solid rocket propellants; solvent for perfume oils; perfume fixative; textile lubricating agent, safety glass; insecticides, printing inks; resin solvent; paper coatings; adhesives; insect repellent for textiles.
East Soldier Creek	12/13	E01, E02, E03, E05, E06, E07, E08, E09, E10, E11, E12, E13	ND to 110.0	E06 (0-6 inch interval)	
West Soldier Creek	2/8	W03, W04	ND to 2,200.0	W03 (0-6 inch interval)	
Tributary A and B	3/6	A02, B02, B03	ND to 30.0	B03 (0-6 inch interval)	

TABLE 4-3 (CONTINUED)
SEDIMENT SEMI-VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB – SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Fluoranthene IDL = 6.28 ug/L (1) Main Soldier Creek East Soldier Creek	1/13 12/13	M07 E01, E02, E03, E04, E05, E06, E07, E08, E09, E10, E11, E12 W01, W02, W03, W04, W06, W07, W08 A01, B01, B02, B03	ND to 26.0 ND to 11,000.0 ND to 11,000.0 ND to 210.0	M07 (6-12 inch interval) E03 (0-6 inch interval) W03 (0-6 inch interval) A01 (0-6 inch interval)	Unknown.
Pyrene IDL = 4.07 ug/L (1) East Soldier Creek	12/13	E01, E02, E03, E04, E05, E06, E07, E08, E09, E10, E11, E12 W01, W02, W03, W04, W06, W07, W08 A01, B03	ND to 10,000.0 ND to 4,600.0 ND to 190.0	E03 (0-6 inch interval) W03 (6-12 inch interval) A01 (0-6 inch interval)	Biochemical research.
West Soldier Creek Tributary A and B	7/8 2/6				
Butylbenzylphthalate IDL = 2.30 ug/L (1) East Soldier Creek West Soldier Creek Tributary A and B	3/13 1/8 1/6	E01, E06, E07 W03 B03	ND to 80.0 ND to 720.0 ND to 76.0	E06 (6-12 inch interval) W03 (0-6 inch interval) B03 (0-6 inch interval)	Plasticizer for polyvinyl and cellulosic resins, organic intermediate.
3,3-Dichlorobenzidine IDL = 22.66 ug/L (1) West Soldier Creek	1/8	W03	ND to 1,700.0	W03 (0-6 inch interval)	Intermediate for dyes and pigments, curing agent for isocyanate-terminated resins for urethane plastics. Dye manufacture
Benzo(a)anthracene IDL = 2.89 ug/L (1) East Soldier Creek	10/13	01, E02, E03, E04, E05, E06, E07, E08, E09, E10 W01, W02, W03, W04, W06, W07, W08 A01, B03	ND to 4,800.0 ND to 4,200.0 ND to 45.0	E03 (0-6 inch interval) W03 (0-6 inch interval) A01 (0-6 inch interval)	
West Soldier Creek Tributary A and B	7/8 2/6				

TABLE 4-3 (CONTINUED)
SEDIMENT SEMI-VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Chrysene IDL = 6.94 ug/L (1) East Soldier Creek	11/13	E01, E02, E03, E04, E05, E06, E07, E08, E09, E10, E11	ND to 5,400.0	E03 (0-6 inch interval)	Organic synthesis.
West Soldier Creek Tributary A and B	7/8 2/6	W01, W02, W03, W04, W06, W07, W08 A01, B03	ND to 7,100.0 ND to 190.0	W03 (0-6 inch interval) A01 (0-6 inch interval)	
Bis(2-ethylhexyl)phthalate IDL = 4.71 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	1/1 13/13 13/13 8/8 6/6	C01 All Locations All Locations All Locations All Locations	ND to 120.0 ND to 1,400.0 ND to 7,000.0 ND to 46,000.0 ND to 710.0	C01 (0-6 inch interval) M11 (6-12 inch interval) E10 (6-12 inch interval) W04 (0-6 inch interval) A02 (6-12 inch interval)	Used in analytical laboratory operations and vacuum pumps.
Di-n-octylphthalate IDL = 5.78 ug/L (1) Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	2/13 10/13 3/8 1/6	M06, M07 E01, E02, E05, E06, E07, E08, E10, E11, E12, E13 W03, W04, W09 B03	ND to 38.0 ND to 540.0 ND to 250.0 ND to 40.0	M06 (0-6 inch interval) E08 (0-6 inch interval) W03 (6-12 inch interval) W04 (0-6 inch interval) B03 (6-12 inch intervals)	Plasticizer for polyvinyl chloride and other vinyls.
Benzo(b)fluoranthene IDL = 7.14 ug/L (1) East Soldier Creek West Soldier Creek Tributary A and B	9/13 6/8 2/6	E01, E02, E03, E05, E06, E07, E08, E09, E10 W01, W02, W03, W04, W06, W08 A01, B03	ND to 5,000.0 ND to 9,200.0 ND to 120.0	E03 (0-6 inch interval) W03 (0-6 inch interval) A01 (0-6 inch interval)	Unknown.

TABLE 4-3 (CONTINUED)
SEDIMENT SEMI-VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB – SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Benzo(k)fluoranthene IDL = 15.21 ug/L (1) East Soldier Creek West Soldier Creek Tributary A and B	8/13 4/8 2/6	E01, E02, E03, E05, E06, E07, E08, E09 W01, W04, W06, W08 A01, B03	ND to 5,300.0 ND to 1,400.0 ND to 230.0	E03 (0-6 inch interval) W04 (0-6 inch interval) A01 (0-6 inch interval)	Unknown.
Benzo(a)pyrene IDL = 2.05 ug/L (1) Main Soldier Creek East Soldier Creek	1/13 11/13	M07 E01, E02, E03, E04, E05, E06, E07, E08, E09, E10, E11 W01, W02, W03, W04, W06, W08	ND to 330.0 ND to 4,100.0	M07 (0-6 inch interval) E03 (0-6 inch interval)	Unknown.
West Soldier Creek	6/8		ND to 4,400.0	W03 (0-6 inch interval)	Biochemical research.
Indeno(1,2,3-cd)pyrene IDL = 6.33 ug/L (1) East Soldier Creek West Soldier Creek	7/13 4/8	E01, E02, E03, E07, E08, E09, E10 W01, W02, W03, W04	ND to 2,100.0 ND to 3,800.0	E03 (0-6 inch interval) W03 (0-6 inch interval)	Suggested as organic photoconductor in copying systems.
Dibenz(a,h)anthracene IDL = 6.92 ug/L (1) East Soldier Creek	2/13	E07, E09	ND to 110.0	E09 (6-12 inch interval)	Product of incomplete combustion.
Benzo (g,h,i)perylene IDL = 7.76 ug/L (1) East Soldier Creek West Soldier Creek	8/13 3/8	E01, E02, E03, E04, E07, E08, E09, E10 W01, W03, W04	ND to 1,300.0 ND to 4,100.0	E03 and E04 (0-6 inch intervals) W03 (0-6 inch interval)	

Legend:

IDL – Instrument Detection Limit.
ND – Not Detected.

Notes:

- (1) The IDL of an individual sediment sample varies with moisture content, therefore no direct comparison can be made between the extract and the sediment sample concentration.
- (2) Frequency of detection refers to the number of locations an analyte was detected versus the total number of locations sampled on that segment.

thirteen locations detected concentrations of di-n-butylphthalate, fluoranthene, bis(2-ethylhexyl)phthalate, di-n-octylphthalate, and benzo(a)pyrene. Di-n-butylphthalate was detected at three (M05, M06, M07) of the thirteen locations, ranging from not detected to 30.0 ug/kg (M07, 0-6 inch interval). Fluoranthene was detected only at location M07 (6-12 inch interval) at a concentration of 26.0 ug/kg. Bis(2-ethylhexyl)phthalate was detected at all Main Soldier Creek sampling locations and ranged in concentrations from not detected to 1,400 ug/kg (M11, 6-12 interval). Di-n-octylphthalate was detected at two (M06, M07) of thirteen locations, ranging from not detected to 38.0 ug/kg (M06, 0-6 inch interval). Benzo(a)pyrene was detected only at location M07 (0-6 inch interval) at a concentration of 330.0 ug/kg. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant and was also detected in the background samples. It is likely the presence of bis(2-ethylhexyl)phthalate is due to laboratory cross-contamination. There appear to be no general trends for the other semi-volatile organics detected by the Phase I analytical results. The Phase I analytical results only indicate random concentrations within the data set. No source of contamination can be readily identified for the other semi-volatile organic contamination.

4.1.2.3 Sediment Semi-Volatile Organic Results for East Soldier Creek Locations. Thirteen locations were investigated during Phase I of the RI along East Soldier Creek. The semi-volatile organic analytical results for these thirteen locations detected the presence of 1,4-dichlorobenzene, 1,3-dichlorobenzene, 1,2-dichlorobenzene, 2-methylphenol, 4-methylphenol, naphthalene, 2-methylnaphthalene, 2-chloronaphthalene, acenaphthene, dibenzofuran, fluorene, phenanthrene, anthracene, di-n-butylphthalate, fluoranthene, pyrene, butylbenzylphthalate, benzo(a)anthracene, chrysene, bis(2-ethylhexyl)phthalate, di-n-octylphthalate, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene. 1,4-Dichlorobenzene was detected at four (E03, E08, E09, E10) of the thirteen locations, ranging from not detected to 4,400 ug/kg (E03, 6-12 inch interval). 1,3-Dichlorobenzene was detected at three (E03, E09, E10) of the thirteen locations ranging from not detected to 280.0 ug/kg (E03, 6-12 inch interval). 1,2-Dichlorobenzene was detected at three (E03, E09, E10) of the thirteen locations, ranging from not detected to 3,100 ug/kg (E03, 6-12 inch interval). 2-Methylphenol was detected only at location E09 (6-12 inch interval) at a concentration of 68.0 ug/kg. 4-Methylphenol was detected only at location E09

(6-12 inch interval) at a concentration of 98.0 ug/kg. Naphthalene was detected at seven (E01, E03, E04, E07, E08, E09, E10) of the thirteen locations, ranging from not detected to 600.0 ug/kg (E09, 6-12 inch interval). 2-Methylnaphthalene was detected at six (E01, E03, E07, E08, E09, E10) of the thirteen locations at concentrations ranging from not detected to 1,900 ug/kg (E03, 6-12 inch interval). 2-Chloronaphthalene was detected at four (E07, E08, E09, E10) of thirteen locations ranging from not detected to 1,600 ug/kg (E08, 0-6 inch interval). Acenaphthene was detected at eight (E01, E02, E04, E06, E07, E08, E09, and E10) of the thirteen locations, ranging from not detected to 250.0 ug/kg (E04, 0-6 inch interval). Dibenzofuran was detected at six (E01, E02, E03, E04, E07, E10) of the thirteen locations ranging from not detected to 340.0 ug/kg at location E03 (0-6 inch interval). Fluorene was detected at five (E01, E02, E07, E09, E10) of the thirteen locations, ranging from not detected to 200.0 ug/kg (E09, 6-12 inch interval). Phenanthrene was detected at eleven (E01, E02, E03, E04, E05, E06, E07, E08, E09, E10, E11) of the thirteen locations at concentrations ranging from not detected to 6,700 ug/kg (E03, 0-6 inch interval). Anthracene was detected at nine (E01, E02, E03, E04, E06, E07, E08, E09, E10) of the thirteen locations, ranging from not detected to 1,500 ug/kg (E03, 0-6 inch interval). Di-n-butylphthalate was detected at all of the East Soldier Creek locations except E04, at concentrations ranging from not detected to 110.0 ug/kg (E06, 0-6 inch interval). Fluoranthene was detected at twelve of the thirteen locations (all except E13), ranging from not detected to 11,000 ug/kg (E03, 0-6 inch interval). Pyrene was detected at all locations except E13, ranging from not detected to 10,000 ug/kg (E03, 0-6 inch interval). Butylbenzylphthalate was detected at three (E01, E06, E07) of the thirteen locations, ranging from not detected to 80.0 ug/kg (E06, 6-12 inch interval). Benzo(a)anthracene was detected at ten (E01, E02, E03, E04, E05, E06, E07, E08, E09, E10) of the thirteen locations, ranging from not detected to 4,800 ug/kg (E03, 0-6 inch interval). Chrysene was detected at all of the East Soldier Creek locations except E12 and E13, ranging from not detected to 5,400 ug/kg (E03, 0-6 inch interval). Bis(2-ethylhexyl)phthalate was detected at all locations with a maximum concentration of 7,000 ug/kg (E10, 6-12 inch interval). Di-n-octylphthalate was detected at ten (E01, E02, E05, E06, E07, E08, E10, E11, E12, E13) of the thirteen locations, ranging from not detected to 540.0 ug/kg (E08, 0-6 inch interval). Benzo(b)fluoranthene was detected at nine (E01, E02, E03, E05, E06, E07, E08, E09, E10) of the thirteen locations ranging from not detected to 5,000 ug/kg (E03, 0-6 inch interval). Benzo(k)fluoranthene was detected at eight (E01,

E02, E03, E05, E06, E07, E08, E09) of the thirteen locations at concentrations ranging from not detected to 5,300 ug/kg (E03, 0-6 inch interval). Benzo(a)pyrene was detected at all of the East Soldier Creek locations except E12 and E13, ranging from not detected to 4,100 ug/kg (E03, 0-6 inch interval). Indeno(1,2,3-cd)pyrene was detected at seven (E01, E02, E03, E07, E08, E09, E10) of the thirteen locations, ranging from not detected to 2,100 ug/kg (E03, 0-6 inch interval). Dibenz(a,h)anthracene was detected only at locations E07 (6-12 inch interval) and E09 (6-12 inch interval) at concentrations of 48.0 ug/kg and 110.0 ug/kg, respectively. Benzo(g,h,i)perylene was detected at eight (E01, E02, E03, E04, E07, E08, E09, E10) of the thirteen locations, ranging from not detected to 1,300 ug/kg (E03 and E04, 0-6 inch interval).

The highest concentrations of semi-volatile organics are on-base and downstream of outfall G that has been documented to have discharged semi-volatile organics (NUS, 1989). The semi-volatile organic concentrations are higher on-base than off-base.

4.1.2.4 Sediment Semi-Volatile Organic Results for West Soldier Creek

Locations. Eight locations were investigated during Phase I of the RI along West Soldier Creek. The semi-volatile organic analytical results for these eight locations detected concentrations of 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, naphthalene, 2-methylnaphthalene, acenaphthene, dibenzofuran, fluorene, phenanthrene, anthracene, di-n-butylphthalate, fluoranthene, pyrene, butylbenzylphthalate, 3,3-dichlorobenzidine, benzo(a)anthracene, chrysene, bis(2-ethylhexyl)phthalate, di-n-octylphthalate, benzo(b)fluoranthene, benzo(k)fluoroanthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene. 1,3-Dichlorobenzene was detected only at location W04 (0-6 inch interval) at a concentration of 210.0 ug/kg. 1,4-Dichlorobenzene was detected only at location W04 (0-6 inch interval) at a concentration of 2,200 ug/kg. 1,2-Dichlorobenzene was detected only at location W04 (0-6 inch interval) at a concentration of 220.0 ug/kg. Naphthalene was detected at four (W03, W06, W07, W08) of the eight locations, ranging from not detected to 690.0 ug/kg (W03, 0-6 inch interval). 2-Methylnaphthalene was detected at four (W03, W06, W07, W08) of the eight locations, ranging from not detected to 1,300 ug/kg (W08, 0-6 inch interval). Acenaphthene was detected at four (W03, W06, W07, W08) of the eight locations, ranging from not detected to 1,100 ug/kg (W03, 0-6 inch interval). Dibenzofuran was

detected only at location W03 (0-6 and 6-12 inch intervals) at concentrations of 480.0 and 290.0 ug/kg, respectively. Fluorene was detected at four (W03, W06, W07, W08) of the eight locations, ranging from not detected to 880.0 ug/kg (W03, 0-6 inch interval). Phenanthrene was detected at seven (W01, W02, W03, W04, W06, W07, W08) of the eight locations, at concentrations ranging from not detected to 6,000 ug/kg (W03, 0-6 inch interval). Anthracene was detected at seven (W01, W02, W03, W04, W06, W07, W08) of the eight locations, ranging from not detected to 1,000 ug/kg (W03, 0-6 inch interval). Di-n-butylphthalate was detected at two (W03, W04) of the eight locations, ranging from not detected to 2,200 ug/kg (W03, 0-6 inch interval). Fluoranthene was detected at seven (W01, W02, W03, W04, W06, W07, W08) of the eight locations, ranging from not detected to 11,000 ug/kg (W03, 0-6 inch interval). Pyrene was detected at seven (W01, W02, W03, W04, W06, W07, W08) of the eight locations, ranging from not detected to 4,600 ug/kg (W03, 6-12 inch interval). Butylbenzylphthalate and 3,3-dichlorobenzidine were detected only at location W03 (0-6 inch interval) at concentrations of 720.0 ug/kg and 1,700 ug/kg, respectively. Benzo(a)anthracene was detected at all of the West Soldier Creek locations except W09, ranging from not detected to 4,200 ug/kg (W03, 0-6 inch interval). Chrysene was detected at seven (W01, W02, W03, W04, W06, W07, W08) of the eight locations, ranging from not detected to 7,100 ug/kg (W03, 0-6 inch interval). Bis(2-ethylhexyl)-phthalate was detected at all locations, at concentrations ranging from not detected to 46,000 ug/kg (W04, 0-6 inch interval). Di-n-octylphthalate was detected at three locations (W03, W04, W09) at concentrations ranging from not detected to 250.0 ug/kg (W03, 6-12 inch interval and W04, 0-6 inch interval). Benzo(b)fluoranthene was detected at six (W01, W02, W03, W04, W06, W08) of the eight locations, ranging from not detected to 9,200 ug/kg (W03, 0-6 inch interval). Benzo(k)fluoranthene was detected at four (W01, W04, W06, W08) of the eight locations, ranging from not detected to 1,400 ug/kg (W04, 0-6 inch interval). Benzo(a)pyrene was detected at six (W01, W02, W03, W04, W06, W08) of the eight locations, ranging from not detected to 4,400 ug/kg (W03, 0-6 inch interval). Indeno(1,2,3-cd)pyrene was detected at four (W01, W02, W03, W04) of the eight locations, ranging from not detected to 3,800 ug/kg (W03, 0-6 inch interval). Benzo(g,h,i)perylene was detected at three (W01, W03, W04) of the eight locations, ranging from not detected to 4,100 ug/kg (W03, 0-6 inch interval). Outfalls A, B, C, D, and E all discharge flows to West Soldier Creek; however, no discharges of semi-volatile organics from these outfalls have been documented (NUS, 1989). The

locations of Outfalls A, B, C, D and E are shown Figure 4-2 (Volume 2). No other on-base potential sources of contamination have been identified.

Five locations (W03, W04, W06, W07, W08) at five depths (0-1, 1-2, 2-3, 3-4, and 4-5 feet) were investigated during Phase II of the RI along West Soldier Creek. Only the W04 0-1 foot interval was investigated for semi-volatile organic contamination. The semi-volatile organic analytical results detected no semi-volatile contamination in the matrix sample from location W04 during Phase II of the RI. No conclusions beyond those drawn based on the Phase I semi-volatile organic analytical results can be made. It appears that the semi-volatile concentrations detected at location W04 are an anomaly in the data set.

4.1.2.5 Sediment Semi-Volatile Organic Results for A and B Tributary

Locations. Six locations were investigated during Phase I of the RI along Tributaries A and B. The semi-volatile analytical results for these six locations detected the presence of phenanthrene, anthracene, di-n-butylphthalate, fluoranthene, pyrene, butylbenzylphthalate, benzo(a)anthracene, chrysene, bis(2-ethylhexyl)phthalate, di-n-octylphthalate, benzo(b)fluoranthene, and benzo(k)fluoranthene. Phenanthrene was detected at two (B01, B03) of the six locations, ranging from not detected to 73.0 ug/kg (B03, 6-12 inch interval). Anthracene was detected only at location B03 (0-6 inch interval) at a concentration of 10.0 ug/kg. Di-n-butylphthalate was detected at three (A03, B02, B03) of the six locations, ranging from not detected to 30.0 ug/kg (B03, 0-6 inch interval). Fluoranthene was detected at four (A01, B01, B02, B03) of the six locations, ranging from not detected to 210.0 ug/kg (A01, 0-6 inch interval). Pyrene was detected at two (A01, B03) of the six locations, ranging from not detected to 190.0 ug/kg (A01, 0-6 inch interval). Butylbenzylphthalate was detected only at location B03 (0-6 inch interval) at a concentration of 76.0 ug/kg. Benzo(a)anthracene was detected at locations A01 (0-6 inch interval) and B03 (6-12 inch interval) at concentrations of 45.0 ug/kg and 38.0 ug/kg, respectively. Chrysene was also only detected at locations A01 (0-6 inch interval) and B03 (6-12 inch interval) at concentrations of 190.0 ug/kg and 82.0 ug/kg, respectively. Bis(2-ethylhexyl)phthalate was detected at all locations with a maximum concentration of 710.0 ug/kg (A02, 6-12 inch interval). Di-n-octylphthalate was detected only at location B03 (0-6 and 6-12 inch intervals) with a maximum concentration of 40.0 ug/kg (6-12 inch interval). Benzo(b)-fluoranthene was detected at two (A01, B03) of the six locations, ranging

from not detected to 120.0 ug/kg (A01, 0-6 inch interval). Benzo(k)fluoranthene was detected at two (A01, B03) of the six locations, ranging from not detected to 230.0 ug/kg (A01, 0-6 inch interval). There is no general trend for the semi-volatile organics detected by the Phase I analytical results. These results indicate random concentrations within the analytical data set. No source of contamination can be identified for these semi-volatile organic concentrations.

4.1.3 Sediment Inorganic Results

Phase I and II of the RI sediment organic analytical results include aluminum, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, vanadium, and zinc. These chemicals of potential concern are identified in the Risk Assessment report (BVWST, 1993a), shown in Table 4-1 (page 4-3), and will be discussed in this subsection. A summary of the sediment inorganic analytical results is shown in Table 4-4 (pages 4-29 through 4-36). The sediment inorganic analytical results are presented on Figures 4-3 and 4-9 in Volume 2 of the RI report, and in Tables B-3 (pages B-8 through B9), B-6 (pages B-17 through B-19), and B-25 through B-41 (pages B-38 through B-54) of Appendix B (Volume 3).

4.1.3.1 Sediment Inorganic Results for Background Locations. Four background samples were collected at off-base locations C01, C02, C03, and D01 during Phase II of the RI. Only background location C01 was sampled during both Phase I and II of the RI.

At location C01, the Phase I analytical results for the 0-6 inch interval detected aluminum [4,050 milligrams per kilogram (mg/kg)], arsenic (1.6 mg/kg), barium (64.4 mg/kg), calcium (4,070 mg/kg), chromium (8.4 mg/kg), cobalt (3.1 mg/kg), copper (36.6 mg/kg), iron (5,780 mg/kg), lead (6.7 mg/kg), magnesium (1,160 mg/kg), manganese (100.0 mg/kg), nickel (8.0 mg/kg), potassium (552.0 mg/kg), silver (0.53 mg/kg), vanadium (9.4 mg/kg), and zinc (13.9 mg/kg).

TABLE 4-4
SEDIMENT INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (mg/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Aluminum IDL = 7.0 ug/L (1)	Background	1/1	C01	4,050.0 to 4,060.0	C01 (6-12 inch interval)	Building and construction, corrosion-resistant chemical equipment, die cast auto parts, electrical industry (power transmission lines), photoengraving plates, permanent magnets, cryogenic technology, machinery and accessory equipment, packaging foil.
	Main Soldier Creek	13/13	All Locations	1,750.0 to 11,000.0	M01 (0-6 inch interval)	
	East Soldier Creek	13/13	All Locations	2,400.0 to 12,300.0	E12 (0-6 inch interval)	
	West Soldier Creek	8/8	All Locations	423.0 to 42,300.0	W07 (0-6 inch interval)	
	Tributary A and B	6/6	All Locations	3,920.0 to 17,600.0	A01 (0-6 inch interval)	
Arsenic IDL = 4.0 ug/L (1)	Background	1/1	C01	1.6	C01 (0-6 and 6-12 inch intervals)	Alloying additive for metals, battery grids, cable sheaths, boiler tubes used to make gallium arsenide for diodes and other electronic devices, doping agent in germanium and silicon solid state products, special solders, medicine.
	Main Soldier Creek	13/13	All Locations	ND to 6.8	M04 (0-6 inch interval)	
	East Soldier Creek	13/13	All Locations	ND to 12.0	E03 (6-12 inch interval)	
	West Soldier Creek	6/8	W03, W04, W06, W07, W08, W09	ND to 5.7	W04 (6-12 inch interval)	
	Tributary A and B	6/6	All Locations	1.3 to 15.7	A01 (6-12 inch interval)	
Barium IDL = 2.0 ug/L (1)	Background	1/1	C01	64.4 to 76.2	C01 (6-12 inch interval)	Getter alloys in vacuum tubes, deoxidizer for copper, Frary's metal, lubricant for anode rotors in x-ray tubes, spark-plug alloys.
	Main Soldier Creek	13/13	All Locations	110.0 to 692.0	M12 (0-6 inch interval)	
	East Soldier Creek	13/13	All Locations	153.0 to 2,910.0	E03 (0-6 inch interval)	
	West Soldier Creek	8/8	All Locations	63.0 to 1,120.0	W04 (6-12 inch interval)	
	Tributary A and B	6/6	All Locations	130.0 to 2,270.0	B02 (6-12 inch interval)	

TABLE 4-4 (CONTINUED)
SEDIMENT INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (mg/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Cadmium IDL, Phase I=3.0 ug/L(1) IDL, Phase II=4.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	0/1	ND	ND	ND	Coatings on metals, alloys, fire protection systems, nickel-cadmium storage batteries, power transmission wire, basis of pigments used in ceramic glazes, machinery enamels, baking enamels, fungicide, photography and lithography, selenium rectifiers, electrodes for cadmium-vapor lamps and photoelectric cells.
	Phase II	3/4	C01, C02, D01	ND to 2.08	C01 (2-3 foot interval)	
	Phase I	8/13	M06, M07, M08, M09, M10, M11, M12, M13	ND to 53.4	M06 (0-6 inch interval)	
	Phase II	3/3	All Locations	ND to 2.5	M09 (0-1 foot interval)	
	Phase I	12/13	E01, E02, E03, E04, E05, E06, E07, E08, E09, E10, E11, E12	ND to 428.0	E09 (6-12 inch interval)	
	Phase II	5/5	All Locations	ND to 12.5	E12 (0-1 foot interval)	
	Phase I	7/8	W01, W02, W03, W04, W06, W07, W08	ND to 93.4	W04 (0-6 inch interval)	
	Phase II	4/5	W03, W04, W06, W07	ND to 15.7	W04 (1-2 foot interval)	
Calcium IDL = 28.0 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	4/6	A01, B01, B02, B03	ND to 17.4	B03 (6-12 inch interval)	Alloying and reducing agent; deoxidizer for alloys; dehydrating oils; decarburization and desulfurization of iron and its alloys; separation of nitrogen from argon; reducing agent in preparation of chromium metal powder, thorium, zirconium, and uranium; fertilizer ingredient.
	Phase I	1/1	C01	775.0 to 4,070.0	C01 (0-6 inch interval)	
	Phase I	13/13	All Locations	691.0 to 32,300.0	M09 (6-12 inch interval)	
	Phase I	13/13	All Locations	779.0 to 72,500.0	E03 (0-6 inch interval)	
	Phase I	8/8	All Locations	1,170.0 to 43,300.0	W09 (6-12 inch interval)	
	Phase I	6/6	All Locations	653.0 to 17,500.0	B02 (6-12 inch interval)	
	Phase I					
	Phase I					

TABLE 4-4 (CONTINUED)
SEDIMENT INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (mg/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Chromium IDL, Phase I=2.0 ug/L(1) IDL, Phase II=7.0 ug/L (1)	Background	1/1	C01	8.0 to 8.4	C01 (0-6 inch interval)	Alloying and plating, chromium-containing and stainless steels, protective coating for automotive and equipment accessories, nuclear and high-temperature research, and constituent of inorganic pigments.
	Phase I	4/4	All Locations	ND to 9.6	C02 (1-2 foot interval)	
	Phase II	13/13	All Locations	4.9 to 829.0	M06 (0-6 inch interval)	
	Phase I	3/3	All Locations	4.6 to 39.0	M09 (0-1 foot interval)	
	Phase II	13/13	All Locations	11.1 to 1,230.0	E09 (6-12 inch interval)	
	Phase I	5/5	All Locations	8.4 to 106.9	E03 (1-2 foot interval)	
	Phase II	8/8	All Locations	11.6 to 2,020.0	W04 (0-6 inch interval)	
Cobalt IDL = 3.0 ug/L (1)	Background	1/1	C01	2.5 to 3.1	C01 (0-6 inch interval)	Alloys electroplating ceramics, lamp filaments, catalyst, fertilizers, glass, drier in printing inks, paints and varnishes, colors, cermets.
	Phase I	13/13	All Locations	2.3 to 9.3	M04 (0-6 inch interval)	
	Phase II	13/13	All Locations	2.8 to 17.3	E03 (0-6 inch interval)	
	Phase I	8/8	All Locations	ND to 52.1	W03 (0-6 inch interval)	
	Phase II	6/6	All Locations	1.8 to 8.5	A01 (0-6 inch interval)	
	Phase I	13/13	All Locations	14.8 to 36.6	C01 (0-6 inch interval)	
	Phase II	12/13	All Locations	ND to 23.6	M06 (0-6 inch interval)	
Copper IDL = 16.0 ug/L (1)	Background	1/1	C01	6.6 to 600.0	E03 (0-6 inch interval)	Electric wiring; switches, plumbing, heating, roofing and building construction; chemical and pharmaceutical machinery; alloys; electroplated protective coatings and undercoats; cooking utensils; corrosion-resistant piping; insecticides; catalyst; antifouling paints.
	Phase I	13/13	M01, M02, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13	6.6 to 320.0	W03 (0-6 inch interval)	
	Phase II	8/8	All Locations	4.8 to 115.0	B01 (6-12 inch interval)	
	Phase I	6/6	All Locations			
	Phase I					
	Phase I					
	Phase I					

TABLE 4-4 (CONTINUED)
SEDIMENT INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (mg/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Cyanide IDL = 0.54 ug/L (1) East Soldier Creek West Soldier Creek	Phase I	1/13	E08	ND to 6.5	E08 (0-6 inch interval)	Extraction of gold and silver from ores, insecticides, fumigant, rodenticide, chelating compound, electroplating, heat treatment of metals, cleaning metals, manufacture of dyes and pigments.
	Phase II	0/5	ND	ND	ND	
	Phase I	1/8	W07	ND to 2.3	W07 (6-12 inch interval)	
	Phase II	0/5	ND	ND	ND	
Iron IDL = 3.0 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	1/1	C01	5,780.0 to 10,700.0	C01 (6-12 inch interval)	Steels and other alloys, source of hydrogen by reaction with steam, powder metallurgy products, magnets, high-frequency cores, auto parts, medicine and dietary supplements.
	Phase I	13/13	All Locations	2,250.0 to 14,900.0	M04 (0-6 inch interval)	
	Phase I	13/13	All Locations	3,750.0 to 41,200.0	E03 (0-6 inch interval)	
	Phase I	8/8	All Locations	827.0 to 10,200.0	W01 (0-6 inch interval)	
	Phase I	6/6	All Locations	4,120.0 to 15,400.0	A01 (0-6 inch interval)	
Lead IDL, Phase I=1.0 ug/L(1) IDL, Phase II=2.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	1/1	C01	6.7 to 7.7	C01 (6-12 inch interval)	Storage batteries, gasoline additive, radiation shielding, cable covering, ammunition, chemical reaction equipment, solder and fusible alloys, vibration damping in heavy construction, foil, bearing alloys.
	Phase II	4/4	All Locations	ND to 54.3	C02 (0-1 foot interval)	
	Phase I	13/13	All Locations	3.9 to 63.6	M06 (0-6 inch interval)	
	Phase II	3/3	All Locations	4.1 to 16.6	M07 (3-4 foot interval)	
	Phase I	13/13	All Locations	5.3 to 586.0	E09 (0-6 inch interval)	
	Phase II	5/5	All Locations	4.5 to 46.7	E06 (0-1 foot interval)	
	Phase I	8/8	All Locations	3.2 to 243.0	W03 (0-6 inch interval)	
	Phase II	5/5	All Locations	3.7 to 152.0	W04 (0-1 foot interval)	
	Phase I	6/6	All Locations	2.2 to 261.0	B02 (6-12 inch interval)	

TABLE 4-4 (CONTINUED)
 SEDIMENT INORGANIC ANALYTICAL SUMMARY
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (mg/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Magnesium IDL = 20.0 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	1/1	C01	734.0 to 1,160.0	C01 (0-6 inch interval)	Aluminum alloys, powder for pyrotechnics and flash photography; production of iron, nickel, zinc, titanium, zirconium; antiknock gasoline additives; cathodic protection; reducing agent; desulfurizing iron in steel manufacture; precision instruments; optical mirrors; dry and wet batteries.
	Phase I	13/13	All Locations	214.0 to 3,380.0	M09 (0-6 inch interval)	
	Phase I	13/13	All Locations	1,220.0 to 20,400.0	E02 (0-6 inch interval)	
	Phase I	8/8	All Locations	179.0 to 15,400.0	W01 (0-6 inch interval)	
	Phase I	6/6	All Locations	486.0 to 6,990.0	B02 (6-12 inch interval)	
Manganese IDL = 1.0 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	1/1	C01	56.4 to 100.0	C01 (0-6 inch interval)	Steel and other alloys, high-purity salt for various chemical uses, purifying and scavenging agent in metal production.
	Phase I	13/13	All Locations	59.9 to 1,490.0	M08 (6-12 inch interval)	
	Phase I	13/13	All Locations	116.0 to 1,460.0	E02 (6-12 inch interval)	
	Phase I	8/8	All Locations	8.8 to 1,080.0	W09 (6-12 inch interval)	
	Phase I	6/6	All Locations	99.8 to 897.0	B02 (6-12 inch interval)	
Mercury IDL = 0.2 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	0/1	ND	ND	ND	Amalgams, catalyst, electrical apparatus, cathodes for production of chlorine and caustic soda, thermometers, barometers, mercury vapor lamps, extractive metallurgy, mirror coating, arc lamps, boilers, coolant and neutron absorber in nuclear power plants.
	Phase I	2/13	M02, M08	ND to 0.3	M02 (6-12 inch interval)	
	Phase I	5/13	E01, E02, E03, E04, E08	ND to 2.6	E03 (0-6 inch interval)	
	Phase I	6/8	W01, W02, W03, W04, W07, W08	ND to 2.6	W08 (6-12 inch interval)	

TABLE 4-4 (CONTINUED)
SEDIMENT INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (mg/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Nickel IDL = 9.0 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	1/1	C01	8.0 to 8.6	C01 (6-12 inch interval)	Alloys, electroplating protective coatings, alkaline storage battery, fuel cell electrodes, catalyst for methanation of fuel gases and hydrogenation of vegetable oils.
	Phase I	13/13	All Locations	2.8 to 122.0	M06 (6-12 inch interval)	
	Phase I	13/13	All Locations	5.7 to 593.0	E03 (6-12 inch interval)	
	Phase I	8/8	All Locations	4.9 to 2,270.0	W03 (0-6 inch interval)	
	Phase I	6/6	All Locations	5.0 to 23.1	B03 (6-12 inch interval)	
Potassium IDL = 345.0 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	1/1	C01	495.0 to 552.0	C01 (0-6 inch interval)	Heat exchange alloys, laboratory reagent, seeding of combustion gases in magnetohydrodynamic generators, component of fertilizers.
	Phase I	13/13	All Locations	ND to 1,320.0	M02 (6-12 inch interval)	
	Phase I	13/13	All Locations	305 to 1,550.0	E12 (0-6 inch interval)	
	Phase I	8/8	All Locations	99.3 to 2,300.0	W01 (0-6 inch interval)	
	Phase I	6/6	All Locations	511.0 to 2,170.0	A01 (0-6 inch interval)	
Selenium IDL = 3.0 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek Tributary A and B	Phase I	0/1	ND	ND	ND	Electronics, xerographic plates, TV cameras, photocells, magnetic computer cores, solar batteries, ceramics, rubber accelerator, catalyst, trace element in animal feeds.
	Phase I	2/13	M03, M13	ND to 0.77	M03 and M13 (0-6 inch interval)	
	Phase I	8/13	E02, E03, E04, E05, E06, E08, E09, E10	ND to 6.6	E03 (0-6 inch interval)	
	Phase I	3/8	W03, W04, W07	ND to 10.2	W04 (6-12 inch interval)	
	Phase I	1/6	B02	ND to 0.73	B02 (6-12 inch interval)	

TABLE 4-4 (CONTINUED)
 SEDIMENT INORGANIC ANALYTICAL SUMMARY
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (mg/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Silver IDL = 2.0 ug/L (1)						
Background	Phase I	1/1	C01	0.53 to 0.91	C01 (6-12 inch interval)	Photographic chemicals; alloys;
Main Soldier Creek	Phase I	9/13	M01, M02, M03, M04, M06, M07, M08, M09, M13	ND to 14.5	M06 (0-6 inch interval)	lining vats and other equipment for chemical reaction vessels;
East Soldier Creek	Phase I	8/13	E02, E03, E04, E06, E07, E08, E09, E10	ND to 24.7	E09 (0-6 inch interval)	electric conductors; silver plating; electronic equipment;
West Soldier Creek	Phase I	7/8	W01, W02, W03, W04, W06, W07, W08	ND to 112.0	W03 (0-6 inch interval)	sterilant; water purification;
Tributary A and B	Phase I	2/6	A01, A02	ND to 1.2	A01 (0-6 inch interval)	surgical cements; hydration and oxidation catalyst; solar cells;
Vanadium IDL = 2.0 ug/L (1)						table cutlery; jewelry; dental, medical, and scientific equipment; electrical contracts; dental amalgams.
Background	Phase I	1/1	C01	8.8 to 9.4	C01 (0-6 inch interval)	Target material for x-rays, alloy
Main Soldier Creek	Phase I	13/13	All Locations	1.4 to 43.8	M04 (0-6 inch interval)	steels, catalyst for sulfuric
East Soldier Creek	Phase I	13/13	All Locations	9.8 to 50.6	E03 (0-6 inch interval)	acid and synthetic rubber.
West Soldier Creek	Phase I	8/8	All Locations	2.9 to 52.9	W04 (6-12 inch interval)	
Tributary A and B	Phase I	6/6	All Locations	9.1 to 34.2	A01 (6-12 inch interval)	

TABLE 4-4 (CONTINUED)
SEDIMENT INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (mg/kg)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Zinc						
IDL = 2.0 ug/L (1)						
Background	Phase I	1/1	C01	10.2 to 13.9	C01 (0-6 inch interval)	Alloys, galvanizing iron and other
Main Soldier Creek	Phase I	13/13	All Locations	3.5 to 53.1	M13 (6-12 inch interval)	metals, electroplating, metal
East Soldier Creek	Phase I	13/13	All Locations	13.0 to 587.0	E09 (0-6 inch interval)	spraying, auto parts, electrical
West Soldier Creek	Phase I	8/8	All Locations	9.0 to 640.0	W04 (6-12 inch interval)	fuses, storage and dry cell
Tributary A and B	Phase I	6/6	All Locations	6.7 to 130.0	B01 (0-6 inch interval)	batteries, fungicides, nutrition, roofing, gutters, engravers' plates, cable wrapping, organ pipes.

Legend:

IDL - Instrument Detection Limit.

ND - Not Detected.

Notes:

- (1) The IDL of an individual sediment sample varies with moisture content, therefore no direct comparison can be made between the extract and the sediment sample concentration.
- (2) Frequency of detection refers to the number of locations an analyte was detected versus the total number of locations sampled on that segment.

At location C01, the analytical results for the 6-12 inch interval detected aluminum (4,060 mg/kg), arsenic (1.6 mg/kg), barium (76.2 mg/kg), calcium (775.0 mg/kg), chromium (8.0 mg/kg), cobalt (2.5 mg/kg), copper (14.8 mg/kg), iron (10,700 mg/kg), lead (7.7 mg/kg), magnesium (734.0 mg/kg), manganese (56.4 mg/kg), nickel (8.6 mg/kg), potassium (495.0 mg/kg), silver (0.91 mg/kg), vanadium (8.8 mg/kg), and zinc (10.2 mg/kg).

Cadmium, chromium and lead were the only chemicals of potential concern detected in the Phase II RI analytical results for location C01. The Phase II RI results for location C01 detected concentrations of cadmium in the 2-3 foot interval (2.08 mg/kg). Chromium was detected in the 0-1 foot interval (6.3 mg/kg), 1-2 foot interval (6.8 mg/kg), 2-3 foot interval (7.3 mg/kg), 3-4 foot interval (6.6 mg/kg) and 4-5 foot interval (4.8 mg/kg). Lead was detected in the 0-1 foot interval (6.5 mg/kg), 1-2 foot interval (5.8 mg/kg), 2-3 foot interval (43.1 mg/kg), 3-4 foot interval (37.4 mg/kg), and 4-5 foot interval (5.5 mg/kg).

The sediment inorganic analytical results for background location C02 detected concentrations of cadmium, chromium, and lead. Cadmium was detected in the 0-1 foot interval (1.3 mg/kg), 1-2 foot interval (1.2 mg/kg), and 4-5 foot interval (1.2 mg/kg). Chromium was detected in the 0-1 foot interval (7.2 mg/kg), 1-2 foot interval (9.6 mg/kg), 2-3 foot interval (7.6 mg/kg), 3-4 foot interval (7.1 mg/kg) and 4-5 foot interval (7.6 mg/kg). Lead was detected in the 0-1 foot interval (54.3 mg/kg), 1-2 foot interval (12.4 mg/kg), 2-3 foot interval (10.9 mg/kg), 3-4 foot interval (10.8 mg/kg), and 4-5 foot interval (33.0 mg/kg).

The sediment inorganic analytical results for location C03 detected the presence of chromium and lead. Chromium was detected in the 0-1 foot interval (5.6 mg/kg), 1-2 foot interval (5.3 mg/kg), 2-3 foot interval (4.6 mg/kg), 3-4 foot interval (7.1 mg/kg), and 4-5 foot interval (7.4 mg/kg). Lead was detected in the 0-1 foot interval (7.6 mg/kg), 1-2 foot interval (4.5 mg/kg), 2-3 foot interval (4.0 mg/kg), 3-4 foot interval (7.7 mg/kg), and 4-5 foot interval (5.4 mg/kg).

The sediment inorganic analytical results for location D01 detected the presence of cadmium, chromium and lead. Cadmium was detected only in the 0-1 foot interval at a concentration of 1.1 mg/kg. Chromium was detected in the 0-1 foot interval (9.3

mg/kg), 1-2 foot interval (8.8 mg/kg), 3-4 foot interval (6.9 mg/kg) and 4-5 foot interval (8.4 mg/kg). Lead was detected in the 0-1 foot interval (28.6 mg/kg), 1-2 foot interval (38.9 mg/kg), 3-4 foot interval (30.0 mg/kg), and 4-5 foot interval (15.2 mg/kg).

4.1.3.2 Sediment Inorganic Results for Main Soldier Creek Locations.

Thirteen locations were investigated during Phase I of the RI along Main Soldier Creek. The inorganic sediment analytical results for these thirteen locations detected levels of aluminum, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, vanadium and zinc. Aluminum was detected at all locations, ranging from 1,750 mg/kg (M12, 0-6 inch interval) to 11,000 mg/kg (M01, 0-6 inch interval). Arsenic was detected at all locations, ranging from not detected to 6.8 mg/kg (M04, 0-6 inch interval). Barium was detected at all locations at concentrations ranging from 110.0 mg/kg (M03, 6-12 inch interval) to 692.0 mg/kg (M12, 0-6 inch interval). Cadmium was detected at eight (M06, M07, M08, M09, M10, M11, M12, M13) of the thirteen locations, ranging from not detected to 53.4 mg/kg (M06, 0-6 inch interval). Calcium was detected at all locations, ranging from 691.0 mg/kg (M03, 0-6 inch interval) to 32,300 mg/kg (M09, 6-12 inch interval). Chromium was detected at all locations, ranging from 4.9 mg/kg (M11, 6-12 inch interval) to 829.0 mg/kg (M06, 0-6 inch interval). Cobalt was detected at all locations, ranging from 2.3 mg/kg (M03, 6-12 inch interval) to 9.3 mg/kg (M04, 0-6 inch interval). Copper was detected at twelve (M01, M02, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13) of thirteen locations, ranging from not detected to 23.6 mg/kg (M06, 0-6 inch interval). Iron was detected at all locations, ranging from 2,250 mg/kg (M11, 6-12 inch interval) to 14,900 mg/kg (M04, 0-6 inch interval). Lead was detected at all locations, ranging from 3.9 mg/kg (M03 and M08 duplicate, 6-12 inch intervals) to 63.6 mg/kg (M06, 0-6 inch interval). Magnesium was detected at all locations, ranging from 214.0 mg/kg (M03, 6-12 inch interval) to 3,380 mg/kg (M09, 0-6 inch interval). Manganese was detected at all locations, ranging from 59.9 mg/kg (M13, 6-12 inch interval) to 1,490 mg/kg (M08, 6-12 inch interval). Mercury was detected at two (M02, M08) of the thirteen locations, ranging from not detected to 0.3 mg/kg (M02, 6-12 inch interval). Nickel was detected at all locations, ranging from 2.8 mg/kg (M03, 6-12 inch interval) to 122.0 mg/kg (M06, 6-12 inch interval). Potassium was detected at all locations, ranging from not detected to 1,320 mg/kg (M02, 6-12 inch interval). Selenium was

detected at two (M03, M13) of thirteen locations, ranging from not detected to 0.77 mg/kg (M03 and M13, 0-6 inch interval). Silver was detected at nine (M01, M02, M03, M04, M06, M07, M08, M09, M13) of the thirteen locations, ranging from not detected to 14.5 mg/kg (M06, 0-6 inch interval). Vanadium was detected at all locations, ranging from 1.4 mg/kg (M11, 6-12 inch interval) to 43.8 mg/kg (M04, 0-6 inch interval). Zinc was detected at all locations, ranging from 3.5 mg/kg (M03, 6-12 inch interval) to 53.1 mg/kg (M13, 6-12 inch interval). Based on the Risk Assessment report, the Phase I RI inorganic analytical results for Main Soldier Creek were at concentrations consistent with background, except for chromium and cadmium (BVWST, 1993a).

Three locations (M07, M08, M09) at five depths (0-1, 1-2, 2-3, 3-4, and 4-5 feet) were investigated during Phase II of the RI along Main Soldier Creek. These locations were investigated further due to the relatively high levels of chemicals of potential concern detected during the Phase I investigation. The Phase II RI inorganic analytical results for these three locations detected concentrations of cadmium, chromium, and lead. Cadmium was detected at all three locations, with a maximum concentration of 2.5 mg/kg (M09, 0-1 foot interval). Chromium was detected at all three locations, with a maximum concentration of 39.0 mg/kg (M09, 0-1 foot interval). Lead was detected at all three locations, with a maximum concentration of 16.6 mg/kg (M07, 3-4 foot interval). No general trends for cadmium, chromium, and lead are evident based on the data.

4.1.3.3 Sediment Inorganic Results for East Soldier Creek Locations. Thirteen locations at two depths (0-6 and 6-12 inch intervals) were investigated during Phase I of the RI along East Soldier Creek. The sediment inorganic analytical results detected concentrations of aluminum, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, vanadium, and zinc. Aluminum was detected at all locations, ranging from 2,400 mg/kg (E03, 0-6 inch interval) to 12,300 mg/kg (E12, 0-6 inch interval). Arsenic was detected at all locations, ranging from not detected to 12.0 mg/kg (E03, 6-12 inch interval). Barium was detected at all locations, ranging from 153.0 mg/kg (E13, 6-12 inch interval) to 2,910 mg/kg (E03, 0-6 inch interval). Cadmium was detected at all of the East Soldier Creek locations except E13, with a maximum concentration of 428.0 mg/kg (E09, 6-12 inch interval). Calcium was

detected at all locations, ranging from 779.0 mg/kg (E13, 0-6 inch interval) to 72,500 mg/kg (E03, 0-6 inch interval). Chromium was detected at all locations, with a maximum concentration of 1,230 mg/kg (E09, 6-12 inch interval). Cobalt was detected at all locations, ranging from 2.8 mg/kg (E07, 6-12 inch interval) to 17.3 mg/kg (E03, 0-6 inch interval). Copper was detected at all locations, ranging from 6.6 mg/kg (E13, 0-6 inch interval) to 600.0 mg/kg (E03, 0-6 inch interval). Cyanide was detected only at location E08 (0-6 and 6-12 inch intervals) at a concentrations of 6.5 mg/kg and 3.4 mg/kg, respectively. Iron was detected at all locations, ranging from 3,750 mg/kg (E02, 0-6 inch interval) to 41,200 mg/kg (E03, 0-6 inch interval). Lead was detected at all locations, ranging from 5.3 mg/kg (E13, 6-12 inch interval) to 586.0 mg/kg (E09, 0-6 inch interval). Magnesium was detected at all locations, ranging from 1,220 mg/kg (E10, 6-12 inch interval) to 20,400 mg/kg (E02, 0-6 inch interval). Manganese was detected at all locations, ranging from 116.0 mg/kg (E11, 6-12 inch interval) to 1,460 mg/kg (E02, 6-12 inch interval). Mercury was detected at five (E01, E02, E03, E04, E08) of the thirteen locations with a maximum concentration of 2.6 mg/kg (E03, 0-6 inch interval). Nickel was detected at all locations, ranging from 5.7 mg/kg (E05, 0-6 inch interval) to 593.0 mg/kg (E03, 6-12 inch interval). Potassium was detected at all locations, ranging from 305.0 mg/kg (E05, 0-6 inch interval) to 1,550 mg/kg (E12, 0-6 inch interval). Selenium was detected at eight (E02, E03, E04, E05, E06, E08, E09, E10) of the thirteen locations, ranging from not detected to 6.6 mg/kg (E03, 0-6 inch interval). Silver was detected at eight (E02, E03, E04, E06, E07, E08, E09, E10) of the thirteen locations with a maximum concentration of 24.7 mg/kg (E09, 0-6 inch interval). Vanadium was detected at all locations, ranging from 9.8 mg/kg (E02, 0-6 inch interval) to 50.6 mg/kg (E03, 0-6 inch interval). Zinc was detected at all locations, ranging from 13.0 mg/kg (E12 and E13, 6-12 inch interval) to 587.0 (E09, 0-6 inch interval). Based on the Risk Assessment report, the Phase I inorganic analytical results for East Soldier Creek were at concentrations consistent with background, except for chromium and cadmium (BVWST, 1993a).

Five locations (E03, E06, E11, E12, E13) at five depths (0-1, 1-2, 2-3, 3-4, and 4-5 feet) were investigated during Phase II of the RI along East Soldier Creek. These locations were investigated further due to the relatively high concentrations of the chemicals of potential concern detected during the Phase I RI. The Phase II RI inorganic analytical results for these five locations detected concentrations of

cadmium, chromium and lead. Cadmium was detected at all locations with a maximum concentration of 12.5 mg/kg (E12, 0-1 foot interval). Chromium was detected at all locations, ranging from 8.4 mg/kg (E13, 2-3 foot interval) to 106.9 mg/kg (E03, 1-2 foot interval). Lead was detected at all locations, ranging from 4.5 mg/kg (E12, 3-4 foot interval) to 46.7 mg/kg (E06, 0-1 foot interval). No general trends for cadmium, chromium, and lead are evident based on the data.

4.1.3.4 Sediment Inorganic Results for West Soldier Creek Locations. Eight locations were investigated during Phase I of the RI along West Soldier Creek. The sediment inorganic analytical results detected concentrations of aluminum, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, vanadium, and zinc. Aluminum was detected at all locations, ranging from 423.0 mg/kg (W02, 0-6 inch interval) to 42,300 mg/kg (W07, 0-6 inch interval). Arsenic was detected at six (W03, W04, W06, W07, W08, W09) of the eight locations with concentrations ranging from not detected to 5.7 mg/kg (W04, 6-12 inch interval). Barium was detected at all locations with concentrations ranging from 63.0 mg/kg (W02, 0-6 inch interval) to 1,120 mg/kg (W04, 6-12 inch interval). Cadmium was detected at seven (W01, W02, W03, W04, W06, W07, W08) of the eight locations at concentrations ranging from not detected to 93.4 mg/kg (W04, 0-6 inch interval). Calcium was detected at all locations, ranging from 1,170 mg/kg (W02, 0-6 inch interval) to 43,300 (W09, 6-12 inch interval). Chromium was detected at all locations at concentrations ranging from 11.6 mg/kg (W02, 0-6 inch interval) to 2,020 mg/kg (W04, 0-6 inch interval). Cobalt was detected at all locations, ranging from not detected to 52.1 mg/kg (W03, 0-6 inch interval). Copper was detected at all locations, ranging from 6.6 mg/kg (W06, 6-12 inch interval) to 320.0 mg/kg (W03, 0-6 inch interval). Cyanide was detected only at location W07 (6-12 inch interval) at a concentration of 2.3 mg/kg. Iron was detected at all locations, ranging from 827.0 mg/kg (W02, 0-6 inch interval) to 10,200 mg/kg (W01, 0-6 inch interval). Lead was detected at all locations, ranging from 3.2 mg/kg (W02, 0-6 inch interval) to 243.0 mg/kg (W03, 0-6 inch interval). Magnesium was detected at all locations, ranging from 179.0 mg/kg (W02, 0-6 inch interval) to 15,400 mg/kg (W01, 0-6 inch interval). Manganese was detected at all locations, ranging from 8.8 mg/kg (W02, 0-6 inch interval) to 1,080 mg/kg (W09, 6-12 inch interval). Mercury was detected at all West Soldier Creek locations except W06 and W09 at concentrations ranging from not detected to 2.6 mg/kg (W08, 6-12 inch interval).

Nickel was detected at all locations with concentrations ranging from 4.9 mg/kg (W02, 0-6 inch interval) to 2,270 mg/kg (W03, 0-6 inch interval). Potassium was detected at all locations, ranging from 99.3 mg/kg (W02, 0-6 inch interval) to 2,300 mg/kg (W01, 0-6 inch interval). Selenium was detected at three (W03, W04, W07) of eight locations, ranging from not detected to 10.2 mg/kg (W04, 6-12 inch interval). Silver was detected at all locations except W09, ranging from not detected to 112.0 mg/kg (W03, 0-6 inch interval). Vanadium was detected at all locations, ranging from 2.9 mg/kg (W02, 0-6 inch interval) to 52.9 mg/kg (W04, 6-12 inch interval). Zinc was detected at all locations at concentrations ranging from 9.0 mg/kg (W09, 6-12 inch interval) to 640.0 mg/kg (W04, 6-12 inch interval). Based on the Risk Assessment report, the Phase I RI inorganic analytical results for West Soldier Creek were at concentrations consistent with background, except for cadmium and chromium (BVWST, 1993a).

Five locations (W03, W04, W06, W07, W08) were investigated during Phase II of the RI along West Soldier Creek. These locations were investigated further due to the relatively high concentrations of the chemicals of potential concern detected during the Phase I investigation. The Phase II inorganic analytical results for these five locations detected concentrations of cadmium, chromium and lead. Cadmium was detected at all West Soldier Creek locations except W08, ranging from not detected to 15.7 mg/kg (W04, 1-2 foot interval). Chromium was detected at all locations, ranging from 15.7 mg/kg (W08, 0-1 foot interval) to 186.0 mg/kg (W04, 1-2 foot interval). Lead was detected at all locations, ranging from 3.7 mg/kg (W08, 0-1 foot interval) to 152.0 mg/kg (W04, 0-1 foot interval). No general trends for cadmium, chromium, and lead are evident based on the data.

4.1.3.5 Sediment Inorganic Results for A and B Tributary Locations. Six locations were investigated during the Phase I of the RI along Tributaries A and B. The sediment inorganic analytical results detected concentrations of aluminum, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, silver, vanadium, and zinc. Aluminum was detected at all locations, ranging from 3,920 mg/kg (A03, 0-6 inch interval) to 17,600 mg/kg (A01, 0-6 inch interval). Arsenic was detected at all locations at concentrations ranging from 1.3 mg/kg (A03, 0-6 and 6-12 inch intervals) to 15.7 mg/kg (A01, 6-12 inch interval). Barium was detected at all locations, ranging from

130.0 mg/kg (A02, 0-6 inch interval) to 2,270 mg/kg (B02, 6-12 inch interval). Cadmium was detected at four (A01, B01, B02, B03) of six locations, ranging from not detected to 17.4 mg/kg (B03, 6-12 inch interval). Calcium was detected at all locations, ranging from 653.0 mg/kg (A03, 6-12 inch interval) to 17,500 mg/kg (B02, 6-12 inch interval). Chromium was detected at all locations, ranging from 6.2 mg/kg (A03, 0-6 inch interval) to 84.8 mg/kg (B01, 0-6 inch interval). Cobalt was detected at all locations, ranging from 1.8 mg/kg (A03, 0-6 inch interval) to 8.5 mg/kg (A01, 0-6 inch interval). Copper was detected at all locations, ranging from 4.8 mg/kg (A03, 0-6 inch interval) to 115.0 mg/kg (B01, 6-12 inch interval). Iron was detected at all locations, ranging from 4,120 mg/kg (A03, 0-6 inch interval) to 15,400 mg/kg (A01, 0-6 inch interval). Lead was detected at all locations, ranging from 2.2 mg/kg (B-01, 0-6 inch interval) to 261.0 mg/kg (B02, 6-12 inch interval). Magnesium was detected at all locations, ranging from 486.0 mg/kg (A03, 0-6 inch interval) to 6,990 mg/kg (B02, 6-12 inch interval). Manganese was detected at all locations, ranging from 99.8 mg/kg (A03, 6-12 inch interval) to 897.0 mg/kg (B02, 6-12 inch interval). Nickel was detected at all locations, ranging from 5.0 mg/kg (A03, 0-6 inch interval) to 23.1 mg/kg (B03, 6-12 inch interval). Potassium was detected at all locations, ranging from 511.0 mg/kg (A03, 0-6 inch interval) to 2,170 mg/kg (A01, 0-6 inch interval). Selenium was only detected at location B02 (6-12 inch interval) at a concentration of 0.73 mg/kg. Silver was detected at two (A01, A02) of the six locations with a maximum concentration of 1.2 mg/kg (A01, 0-6 inch interval). Vanadium was detected at all locations, ranging from 9.1 mg/kg (A03, 0-6 inch interval) to 34.2 mg/kg (A01, 6-12 inch interval). Zinc was detected at all locations, ranging from 6.7 mg/kg (A02, 0-6 inch interval) to 130.0 mg/kg (B01, 0-6 inch interval).

Because the Phase I inorganic analytical results for Tributaries A and B were at concentrations consistent with background, based on the Risk Assessment report (BVWST, 1993a), no samples were collected along Tributaries A and B during Phase II of the RI.

4.1.4 Sediment Toxicity Characteristic Leaching Procedure Results

The TCLP analysis was performed only during Phase II of the RI and only on samples collected from M07 (0-1 foot interval), M08 (0-1 interval), M09 (0-1 and 1-2 foot intervals), E11 (0-1 foot interval), E12 (0-1 foot interval), E13 (0-1 foot interval), W03 (0-1 foot interval), W04 (0-1 and 1-2 foot interval), W07 (0-1 foot interval), and

W08 (0-1 foot interval). The TCLP analytical results are shown in Tables B-42 through B-51 (pages B-55 through B-64) of Appendix B (Volume 2).

The TCLP analysis included volatile and semi-volatile organic, and metal analytes. The TCLP analytical results included benzene, chloroform, arsenic, barium, cadmium, chromium, and lead.

Benzene was detected at two (E13, M07) of the ten locations at concentrations ranging from not detected to 180.0 micrograms per liter (ug/L) (E13, 0-1 foot interval). Chloroform was detected at nine of the ten locations (except W03) at concentrations ranging from not detected to 10.0 ug/L (E12 and W07, 0-1 foot interval). Arsenic was detected at only location E13 (0-1 foot interval) at a concentration of 63.0 milligrams per liter (mg/L). The high concentration of arsenic could be the result of naturally occurring arsenic in the sediment. Barium was detected at all locations at concentrations ranging from not detected to 3.65 mg/L (W03, 0-1 foot interval). Cadmium was detected at all locations at concentrations ranging from not detected to 8.4 mg/L (M09, 1-2 foot interval). Chromium was detected at five (M07, M09, E11, E13, W04) of the ten locations at concentrations ranging from not detected to 7.0 mg/L (M09, 1-2 foot interval). Lead was detected at two (W04, W07) of the ten locations at concentrations ranging from not detected to 0.28 mg/L (W04, 0-1 foot interval).

The maximum regulatory-based concentration for the TCLP was exceeded for arsenic, cadmium, and chromium. Arsenic exceed its maximum regulatory-based concentration of 5.0 mg/L only at location E13 (63.0 mg/L, 0-1 foot interval). Cadmium exceeded its maximum regulatory-based concentration of 1.0 mg/L only at location M09 (8.4 mg/L, 1-2 foot interval). Chromium exceeded its maximum regulatory-based concentration of 5.0 mg/L only at location M09 (7.0 mg/L, 1-2 foot interval). The dissimilar matrix and duplicate arsenic concentrations could be due to an unrepresentative duplicate sample caused by not completely mixing the sample volume.

4.1.5 Sediment Physical Property Parameters

Sediment samples were collected and analyzed for total organic carbon, field density, liquid limit, plasticity index, unified soil classification, sediment particle size fractions

and gradations, water content, and soil moisture at two depths (0-6 and 6-12 inch intervals) from each of eight locations (A01, C01, E09, M05, M08, M09, M13, and W06) during Phase I of the RI. The Phase I sediment physical parameter data is shown in Tables B-52 through B-69 (pages B-65 through B-82) of Appendix B (Volume 3) excluding sediment particle size distribution and gradations. The physical parameters were analyzed for use in development and evaluation of potential remedial technologies.

Total organic carbon ranged from 0.3% to 0.8% (C01, 0-6 inch interval). The field density ranged from 116.9 pounds per cubic foot (lbs/ft³) (E09, 6-12 inch interval) to 131.1 lbs/ft³ (A01, 0-6 inch interval). The water content ranged from 9.4% (A01, 0-6 inch interval) to 37.2% (E09, 6-12 inch interval). The liquid limit ranged from 18.2% (M08, 6-12 inch interval) to 45.2% (A01, 0-6 inch interval). The plastic limit ranged from 14.3% (C01, 6-12 inch interval) to 18.1% (A01, 6-12 inch interval). The plasticity index (the difference between the plastic and liquid limits) ranged from 2.4% (M08, 6-12 inch interval) to 27.7% (A01, 0-6 inch interval). The unified soil classifications are presented in Section 3.0 of this report. The soil moisture ranged from 20% (C01, 6-12 inch interval) to 23.4% (M13, 6-12 inch interval).

Composite sediment samples were collected and analyzed for total organic carbon, field density, liquid limit, plastic limit, unified soil classification and water content at all Phase II RI locations except location E06. The Phase II physical parameter data is shown in Tables B-54 through B-69 (pages B-67 through B-82). Total organic carbon ranged from 720.0 mg/kg (E12, 3-4 foot interval) to 13,400 mg/kg (E12, 0-1 foot interval). Field density ranged from 15.26 lbs/ft³ (C01, 4-5 foot interval) to 127.09 lbs/ft³ (W06, 0-1 foot interval). Liquid limit ranged from 0% (D01, 3-4 foot interval and W07, 0-1 foot interval) to 34.0% (M07, 0-1 foot interval). Plastic limit ranged from 0% (C03, D01, W07 at several depths) to 19.0% (C02, 2-3 foot interval). The plasticity index ranged from 0% (C03, D01, W07 at several depths) to 17% (M07, 0-1 and 1-2 foot intervals). The unified soil classification was presented in Section 3.0 of this report.

Sediment particle size fractions and gradations were also evaluated from field samples. Particle size fractions and gradation were determined to characterize contaminant transport in the Soldier Creek sediments. Laboratory sieve tests were

performed on sediment samples from locations W06, M08, M09, M13, E01, E09, and A01. All other samples consisted of cohesive materials which could not be analyzed with a sieve. Particle distribution curves for each sample indicate that the sediment samples are intermediate to fully matured uniform soils. Sediment samples from M09, M13, E01, A01, and W06 were very fine sands to silt or clay with over 80 percent of the sample passing the No. 200 sieve. These analyses indicate that Soldier Creek samples are comprised of silts, clays, or very fine grained materials which would readily retard dissolved contaminants via adsorption and possibly retain suspended solids via filtration.

4.1.6 Summary of Sediment Results

Volatile organics, semi-volatile organics, and inorganics were detected in samples along Tributaries A, B, C, and D, and East, Main, and West Soldier Creeks.

The volatile organics detected in the samples are described in Subsection 4.1.1. When the concentration of common laboratory contaminants (methylene chloride, acetone, and toluene) was less than ten times the CRQL, it was concluded that this contamination was due to cross-contamination. In general, the concentrations of 1,2-dichloroethene (total), trichloroethene, benzene, tetrachloroethene, chlorobenzene, ethylbenzene, and xylene (total) were low and no trends could be established. In general, there appeared to be higher volatile organic concentrations on-base and at depths greater than 0-6 inch interval. This is likely due to the high mobility of volatile organics. It is unlikely that volatile organics would be present at deeper intervals based on the clayey geology which lies just below the Soldier Creek sediment that retards contaminant migration.

The semi-volatile organics detected in the samples are described in Subsection 4.1.2. In general, no source of contamination could be readily identified for the semi-volatile organics except on-base along East Soldier Creek. The highest concentrations of semi-volatile organics were downstream of Outfall G (shown on Figures 4-1 through 4-3, and 4-7 through 4-9, Volume 2) that has been known to discharge semi-volatile organics to East Soldier Creek in the past (NUS, 1989).

The inorganics detected in the samples are described in Subsection 4.1.3. No general trends for inorganic chemicals of potential concern were concluded.

4.2 Surface Water Results

Forty-eight composite and grab surface water samples were collected during Phase I and II of the RI, as described in Subsections 2.2.2 and 2.3.2. Composite and discrete grab surface water samples were collected from the mid-water column during Phase I and II of the RI. The composite surface water samples were analyzed for semi-volatile organics on the TCL, and metals including cyanide on the TAL in Phase I of the RI, and metals (antimony, cadmium, chromium, lead) and cyanide were analyzed in Phase II of the RI samples. The composite surface water samples were also submitted for SAS analysis in Phase I and II of the RI including alkalinity, hardness, COD, TSS, BOD₅, TOC, and nitrates. Field measurements performed on composite surface water samples included temperature, specific conductivity, dissolved oxygen, and pH. The discrete grab samples were analyzed for volatile organics on the TCL during Phase I and II of the RI. Surface water analytical data for compounds detected above the detection limit are presented on Figures 4-4, 4-5, 4-6, 4-10, and 4-11 in Volume 2 of the RI report. The complete surface water analytical data, including all non-detected compounds, are presented in Tables B-70 through B-125 (pages B-83 through B-143) of Appendix B (Volume 3). The Phase I and II sampling locations are illustrated on Figures 2-1 (page 2-5) and 2-2 (page 2-11), respectively.

4.2.1 Surface Water Volatile Organic Results

The Phase I and II surface water volatile organic analytical results including methylene chloride, acetone, carbon disulfide, chlorobenzene, 1,2-dichloroethene (total), chloroform, 1,1,1-trichloroethane, bromodichloromethane, trichloroethene, dibromochloromethane, benzene, bromoform, tetrachloroethene, toluene, and xylene (total) will be discussed in this subsection. These compounds are identified as chemicals of potential concern in the Risk Assessment report (BVWST, 1993a). A summary of the detected surface water volatile organic analytical results is shown in Table 4-5 (pages 4-48 through 4-51). The surface water volatile organic analytical results are presented on Figures 4-4 and 4-10 in Volume 2 of the RI report, and in

Tables B-70 (pages B-83 through B-84), and B-73 through B-89 (pages B-90 through B-106) of Appendix B (Volume 3).

TABLE 4-5
SURFACE WATER VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Methylene Chloride IDL = 0.37 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	0/1	ND	ND	ND	Paint remover, solvent degreasing, plastics processing, blowing agent in foams, solvent extraction, solvent in cellulose acetate, aerosol propellant.
	Phase II	1/4	C02	ND to 0.8	C02	
	Phase I	6/13	M01, M04, M05 M08, M09, M12	ND to 6.0	M08	
	Phase II	3/3	All Locations	0.9 to 2.0	M07	
	Phase I	3/13	E01, E02, E03	ND to 6.0	E02	
	Phase II	5/5	All Locations	3.0 to 620.0	E12	
	Phase I	3/8	W03, W04, W08	ND to 14.0	W03	
	Phase II	3/5	W03, W07, W08	ND to 2.0	W03, W07	
Acetone IDL = 0.69 ug/L (1) Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	0/13	ND	ND	ND	Paint, varnish, and lacquer solvent; cellulose acetate, especially as spinning solvent; to clean and dry parts of precision equipment; solvent for potassium iodide and permanganate; delusterant for cellulose acetate fibers; specification testing of vulcanized rubber products.
	Phase II	1/3	M07	ND to 7.0	M07	
	Phase I	1/13	E03	ND to 5.0	E03	
	Phase II	3/5	E03, E11, E12	ND to 60.0	E12	
	Phase I	0/8	ND	ND	ND	
	Phase II	2/5	W04, W07	ND to 34.0	W04	
1,2-Dichloroethene (Total) IDL = 0.41 ug/L (1) West Soldier Creek	Phase I	1/8	W03	ND to 8.0	W03	General solvent for organic materials, dye extraction, perfumes, lacquers, thermoplastics, organic synthesis.
	Phase II	1/5	W04	ND to 14.0	W04	

TABLE 4-5 (CONTINUED)
 SURFACE WATER VOLATILE ORGANIC ANALYTICAL SUMMARY
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Dibromochloromethane IDL = 0.23 ug/L (1) East Soldier Creek	Phase I	3/13	E09, E10, E11	ND to 5.0	E09, E10	Organic synthesis.
	Phase II	0/5	ND	ND	ND	
Chloroform IDL = 0.78 ug/L (1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	0/1	ND	ND	ND	Fluorocarbon, plastics, solvent, analytical chemistry, fumigant, insecticides.
	Phase II	1/4	C03	ND to 9.0	C03	
	Phase I	6/13	M01, M04, M08 M10, M12, M13	ND to 5.0	M01, M04, M13	
	Phase II	0/3	ND	ND	ND	
	Phase I	5/13	E01, E02, E03, E09, E11	ND to 6.0	E09	
	Phase II	0/5	ND	ND	ND	
1,1,1-Trichloroethane IDL = 0.36 ug/L (1) Main Soldier Creek East Soldier Creek	Phase I	4/8	W02, W03, W04, W08	ND to 5.0	W02	Metal degreasing; extraction solvent for oils, fats, waxes; solvent dyeing; dry cleaning; refrigerant and heat exchange liquid; fumigant; cleaning and drying electronic parts; diluent in paints and adhesives; textile processing; chemical intermediate; aerospace operations (flushing liquid oxygen).
	Phase II	0/5	ND	ND	ND	
	Phase I	0/13	ND	ND	ND	
	Phase II	3/3	All Locations	1.0 to 3.0	M08	
	Phase I	1/13	E09	ND to 2.0	E09	
	Phase II	2/5	E12, E13	ND to 5.0	E12	

TABLE 4-5 (CONTINUED)
SURFACE WATER VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Bromodichloromethane IDL = 0.17 ug/L (1) Background East Soldier Creek	Phase I	0/1	ND	ND	ND	Unknown.
	Phase II	1/4	C03	ND to 0.9	C03	
	Phase I	3/13	E09, E10, E11	ND to 6.0	E09	
	Phase II	0/5	ND	ND	ND	
Bromoform IDL = 0.72 ug/L (1) East Soldier Creek	Phase I	1/13	E11	ND to 4.0	E11	Intermediate organic synthesis, geological assaying, solvent for waxes, greases, and oil, medicine
	Phase II	2/5	E03, E06	ND to 15.0	E03	
Tetrachloroethene IDL = 0.35 ug/L (1) East Soldier Creek West Soldier Creek	Phase I	3/13	E09, E10, E11	ND to 3.0	E09, E10	Dry cleaning solvent, vapor degreasing solvent, drying agent for metals and certain other solids, vermituge, heat-transfer medium, manufacture of fluorocarbon.
	Phase II	0/5	ND	ND	ND	
	Phase I	0/8	ND	ND	ND	
	Phase II	2/5	W04, W08	ND to 6.0	W08	
Benzene IDL = 0.33 ug/L(1) Main Soldier Creek East Soldier Creek	Phase I	0/13	ND	ND	ND	Manufacturing of ethylbenzene (for styrene monomer); dodecylbenzene (for detergents); cyclohexane (for nylon); phenol; nitrobenzene (for aniline); maleic anhydride; chlorobenzene; diphenyl; benzene hexachloride; benzene-sulfonic acid; as a solvent.
	Phase II	1/3	M09	ND to 2.0	M09	
	Phase I	0/13	ND	ND	ND	
	Phase II	1/5	E13	ND to 1.0	E13	

TABLE 4-5 (CONTINUED)
 SURFACE WATER VOLATILE ORGANIC ANALYTICAL SUMMARY
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Toluene IDL = 0.85 ug/L(1) Main Soldier Creek East Soldier Creek	Phase I	0/13	ND	ND	ND	Aviation gasoline and high octan blending stock; benzene, phenol, and caprolactam; solvent for pai and coatings, gums, resins, most oils, rubber, vinyl organosols; diluent and thinner in nitrocellulose lacquers; adhesive solvent in plastic toys and model airplanes; chemical (benzoic aci benzyl and benzoyl derivatives, saccharin, medicines dyes, perfumes); source of toluene disocyanates (polyurethane resin explosives; toluene sulfonates (detergents); scintillation counters.
	Phase II	2/3	M07, M09	ND to 5.0	M07	
	Phase I	1/13	E02	ND to 1.0	E02	
	Phase II	2/5	E11, E13	ND to 4.0	E11, E13	
Chlorobenzene IDL = 0.87 ug/L (1) Background Main Soldier Creek	Phase I	0/1	ND	ND	ND	Phenol, chloronitrobenzene, aniline, solvent carrier for methylene diisocyanate, solvent, pesticide intermediate, heat transfer.
	Phase II	1/4	D01	ND to 1.0	D01	
	Phase I	0/13	ND	ND	ND	
	Phase II	1/3	M09	ND to 2.0	M09	
Trichloroethene IDL = 0.54 ug/L (1) Main Soldier Creek West Soldier Creek	Phase I	0/13	ND	ND	ND	Solvent, fire extinguishers, chemical intermediate, blowing agent.
	Phase II	1/3	M09	ND to 2.0	M09	
	Phase I	0/8	ND	ND	ND	
	Phase II	1/5	W04	ND to 2.0	W04	

TABLE 4-5 (CONTINUED)
 SURFACE WATER VOLATILE ORGANIC ANALYTICAL SUMMARY
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Carbon Disulfide IDL = 0.43 ug/L (1) Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	0/13	ND	ND	ND	Viscose rayon, cellophane, manufacture of carbon tetrachloride and flotation agents, solvent.
	Phase II	2/3	M08, M09	ND to 0.7	M08, M09	
	Phase I	0/13	ND	ND	ND	
	Phase II	1/5	E03	ND to 1.0	E03	
	Phase I	0/8	ND	ND	ND	
	Phase II	1/5	W03	ND to 1.0	W03	
Xylene (Total) IDL = 0.55 ug/L (1) East Soldier Creek	Phase I	0/13	ND	ND	ND	Aviation gasoline; protective coatings; solvent for alkyd resins, lacquers, enamels, rubber cements; synthesis of organic chemicals.
	Phase II	1/5	E13	ND to 2.0	E13	

4.2.1.1 Surface Water Volatile Organic Results for Background Locations.

Four background samples were collected during Phase II of the RI at off-base locations C01, C02, C03, and D01. Only background location C01 was sampled during both Phase I and II of the RI.

The Phase I and II analytical results for location C01 detected no concentrations of volatile organics. The Phase II analytical results for location C02 detected a concentration of methylene chloride at 0.8 micrograms per liter (ug/L). The Phase II analytical results for location C03 detected concentrations of chloroform and bromodichloromethane at 9.0 ug/L and 0.9 ug/L, respectively. The Phase II analytical results for location D01 detected chlorobenzene at a concentration of 1.0 ug/L.

4.2.1.2 Surface Water Volatile Organic Results for Main Soldier Creek Locations.

Thirteen surface water locations were sampled at the mid-water column during Phase I of the RI along Main Soldier Creek. The surface water volatile organic analytical results for the thirteen locations indicate concentrations of methylene chloride and chloroform. Methylene chloride was detected at six (M01, M04, M05, M08, M09, M12) of the thirteen locations at concentrations ranging from not detected to 6.0 ug/L (M08). Chloroform was detected at six (M01, M04, M08, M10, M12, M13) of the thirteen locations at concentrations ranging from not detected to 5.0 ug/L (M01, M04, M13). Methylene chloride is a common laboratory contaminant. Because the methylene chloride concentrations do not exceed ten times the CRQL, it is likely the concentrations are due to laboratory cross-contamination.

Three locations (M07, M08, M09) were investigated during Phase II of the RI along Main Soldier Creek. The volatile organic results for these three locations indicate the presence of methylene chloride, acetone, 1,1,1-trichloroethane, trichloroethene, carbon disulfide, benzene, toluene, and chlorobenzene. Methylene chloride was detected at all three locations, ranging from 0.9 ug/L (M09) to 2.0 ug/L (M07). Acetone was detected only at location M07 at a concentration of 7.0 ug/L. Carbon disulfide was detected at two (M08, M09) of three locations ranging from not detected to 0.7 ug/l (M08, M09). Trichloroethene and benzene were detected at location M09, both at a concentrations of 2.0 ug/L. Toluene was detected at locations M07 and M09 at concentrations of 5.0 ug/L and 4.0 ug/L, respectively. Chlorobenzene was detected at location M09 at a concentration of 2.0 ug/L. The

presence of methylene chloride, acetone, and toluene in the Phase II analytical results is likely due to laboratory cross-contamination. Building 3001 outfalls have been identified as a source of 1,1,1-trichloroethane, trichloroethene, and benzene (NUS, 1989). Chlorobenzene use at Tinker AFB has not been documented, therefore, it appears to be an anomaly from the general trend illustrated in the analytical data set. A salvage yard and service station are adjacent to this portion of Main Soldier Creek, although no source of contamination can be concluded from this investigation. While locations M07, M08, and M09 are located downstream of Building 3001 outfalls, these locations are almost one mile downstream of the Building 3001 outfalls, and receive surface runoff from the salvage yard and service station. Due to the locations and concentrations of 1,1,1-trichloroethane, trichloroethene, benzene, and chlorobenzene in the off-base surface water, it is impossible to conclusively identify sources of contamination at these locations and to conclusively state whether off-base migration is the source of contamination at these locations.

4.2.1.3 Surface Water Volatile Organic Results for East Soldier Creek

Locations. Thirteen surface water locations along East Soldier Creek were investigated during Phase I of the RI. Methylene chloride, acetone, chloroform, 1,1,1-trichloroethane, bromodichloromethane, dibromochloromethane, bromoform, tetrachloroethene, and toluene were detected along East Soldier Creek. Methylene chloride was detected at three (E01, E02, E03) of the thirteen locations, ranging from not detected to 6.0 ug/L (E02). Acetone was detected only at location E03 at a concentration of 5.0 ug/L. Chloroform was detected at five (E01, E02, E03, E09, E11) of the thirteen locations, ranging from not detected to 6.0 ug/L (E09). 1,1,1-Trichloroethane was detected only at location E09 at a concentration of 2.0 ug/L. Bromodichloromethane was detected at three (E09, E10, E11) of the thirteen locations, ranging from not detected to 6.0 ug/L (E09). Bromoform was detected only at location E11 at a concentration of 4.0 ug/L. Dibromochloromethane was detected at three (E09, E10, E11) of the thirteen locations at concentrations ranging from not detected to 5.0 ug/L (E09, E10). Tetrachloroethene was detected at three (E09, E10, E11) of the thirteen locations, ranging from not detected to 3.0 ug/L (E09, E10). Toluene was detected only at location E02 at a concentration of 1.0 ug/L. Methylene chloride, acetone, and chloroform are common laboratory contaminants. Because the methylene chloride, acetone, and chloroform concentrations do not exceed ten times the CRQL, it is likely that these concentrations are due to

laboratory cross-contamination. The relatively high concentrations of volatile organics are on-base and downstream of Outfall G that has been documented to have discharged volatile organics to East Soldier Creek (NUS, 1989). The location of Outfall G is shown on Figure 4-10 (Volume 2). There were no relatively high concentrations of volatile organics off-base.

Five locations (E03, E06, E11, E12, E13) were investigated during Phase II of the RI along East Soldier Creek. Methylene chloride, acetone, carbon disulfide, bromoform, toluene, 1,1,1-trichloroethane, benzene and xylene (total) were detected at the five locations. Methylene chloride was detected at all five locations, ranging from 3.0 ug/L (E13) to 620.0 ug/L (E12). Acetone was detected at three (E03, E11, E12) of the five locations, ranging from not detected to 60.0 ug/L (E12). Carbon disulfide was detected only at location E03, at a concentration of 1.0 ug/L. Bromoform was detected at two (E03, E06) of the five locations, ranging from not detected to 15.0 ug/L (E03). Toluene concentrations of 4.0 ug/L were detected at locations E11 and E13. 1,1,1-Trichloroethane was detected only at locations E12 and E13, at concentrations of 5.0 ug/L and 2.0 ug/L, respectively. Benzene and xylene (total) were detected only at location E13 at 1.0 ug/L and 2.0 ug/L, respectively. Carbon disulfide and bromoform use at Tinker AFB has not been documented, therefore, these concentrations appear to be an anomaly from the general trend illustrated in the analytical data set. The general trend for the Phase II analytical results is higher volatile organic contamination off-base at E11, E12 and E13. It is difficult to assess the source of contamination in these off-base locations. There are car and engine repair operations adjacent to E11, E12, and E13 that may be contributing to the contamination. The car and engine repair operations are shown on Figure 4-4 (Volume 2). While locations M07, M08, and M09 are located downstream of Building 3001 outfalls, these locations are approximately one-half mile downstream of the Building 3001 outfalls and receive surface runoff from the car and engine facility. Building 3001 outfalls have been identified as a source of 1,1,1-trichloroethane contamination. These facts, taken together with the low concentrations of these contaminants, make it impossible to conclusively state whether off-base migration is the source of contamination at these locations.

4.2.1.4 Surface Water Volatile Organic Results for West Soldier Creek Locations. Eight surface water locations were sampled at the mid-water column

during Phase I of the RI along West Soldier Creek. The surface water volatile organic analytical results for these eight locations detected the presence of methylene chloride, 1,2-dichloroethene, and chloroform. Methylene chloride was detected at three (W03, W04, W08) of the eight locations, ranging from not detected to 14 ug/L (W03). 1,2-Dichloroethene (total) was detected only at location W03, at a concentration of 8.0 ug/L. Chloroform was detected at four (W02, W03, W04, W08) of the nine locations, ranging from not detected to 5.0 ug/L (W02). Methylene chloride and chloroform are common laboratory contaminants. The presence of these contaminants in the Phase I RI analytical results is probably due to laboratory cross-contamination. 1,2-Dichloroethene is a common solvent used in cleaning engine parts. It is possible that the presence of 1,2-dichloroethene is due to surface runoff from the Tinker AFB runway which is directly adjacent to West Soldier Creek. The general trend for West Soldier Creek appears to be relatively higher volatile organic concentrations on-base than off-base.

Five locations (W03, W04, W06, W07, W08) were investigated during Phase II of the RI along West Soldier Creek. Methylene chloride, acetone, carbon disulfide, 1,2-dichloroethene, trichloroethene, and tetrachloroethene were detected. Methylene chloride was detected at three (W03, W07, W08) of the five locations, ranging from not detected to 2.0 ug/L (W03 and W07). Acetone was detected at locations W04 (34.0 ug/L) and W07 (4.0 ug/L). Tetrachloroethene was detected at locations W04 (1.0 ug/L) and W08 (6.0 ug/L). Contaminants detected at single locations only include carbon disulfide (W03 at 1.0 ug/L), 1,2-dichloroethene (total) (W04 at 14.0 ug/L), and trichloroethene (W04 at 2.0 ug/L). The presence of methylene chloride and acetone in the Phase II RI analytical results is likely due to laboratory cross-contamination. Carbon disulfide, 1,2-dichloroethene, trichloroethene, and tetrachloroethene are common solvents used in cleaning engine parts. It is possible that the presence of these contaminants is due to surface runoff from the Tinker AFB runway which is directly adjacent to West Soldier Creek. The Phase II analytical data repeats a similar trend noted in the Phase I analytical data; relatively higher organic concentrations were located on-base.

4.2.1.5 Surface Water Volatile Organic Results for A and B Tributary Locations. There were no surface water samples collected along Tributaries A and B in Phase I of the RI because these tributaries did not contain surface water during

July 1990. These tributaries were not investigated during Phase II of the RI because of the relatively low concentrations of the chemicals of potential concern detected in the sediment in Phase I of the RI and little, if any, water was likely to be present in these drainages.

4.2.2 Surface Water Semi-Volatile Organic Results

The Phase I surface water semi-volatile organic analytical results for benzoic acid, fluoranthene, pyrene, chrysene, and benzo(g,h,i)perylene will be discussed in this subsection. These chemicals are identified as chemicals of potential concern in the Risk Assessment report (BVWST, 1993a). A summary of the detected surface water semi-volatile organic analytical results is shown in Table 4-6 (page 4-58). The surface water semi-volatile organic analytical results are presented on Figure 4-5 in Volume 2 of the RI report, and Table B-71 (pages B-85 through B-87) of Appendix B (Volume 3).

4.2.2.1 Surface Water Semi-Volatile Organic Results for Background Location.

The Phase I RI surface water semi-volatile analytical results detected no concentration of contaminants. No background surface water semi-volatile organic sample was collected during Phase II of the RI due to no contamination found during Phase I of the RI.

4.2.2.2 Surface Water Semi-Volatile Organic Results for Main Soldier Creek

Locations. Thirteen locations were investigated during Phase I of the RI along Main Soldier Creek. Two (M02, M03) of the thirteen locations were dry and no surface water samples were collected. Benzoic acid was the only contaminant detected at location M06 at a concentration of 0.4 ug/L. Di-n-butylphthalate was detected at location M05 and M11 with concentrations of 0.4 ug/L and 0.3 ug/L, respectively.

Bis(2-ethylhexyl)phthalate was detected at five (M01, M04, M05, M08, M12) of the thirteen locations with concentrations ranging from not detected to 10.0 ug/L (M08). No general trends or source of contamination for the Phase I RI surface water analytical results can be established.

TABLE 4-6
SURFACE WATER SEMI-VOLATILE ORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	FREQUENCY OF DETECTION (2)	LOCATION ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Benzoic Acid IDL = 47.61 ug/L(1) Main Soldier Creek	1/13	M06	ND to 0.4	M06	Sodium and butyl benzoates; plasticizers; benzoyl chloride alkyd resins; food preservative; seasoning tobacco; flavors; perfumes; dentifrices; standard in analytical chemistry; antifungal agent.
	1/13	E12	ND to 0.4	E12	
Chrysene IDL = 6.94 ug/L(1) East Soldier Creek	1/13	E05	ND to 5.0	E05	Organic synthesis.
Fluoranthene IDL = 6.28 ug/L(1) West Soldier Creek	1/8	W03	ND to 1.0	W03	Unknown.
Pyrene IDL = 4.07 ug/L(1) West Soldier Creek	1/8	W03	ND to 1.0	W03	Biochemical research.
Benzo(g,h,i)perylene IDL = 7.76 UG/l (1) East Soldier Creek	1/13	E05	ND to 6.0	E05	Product of incomplete combustion.

Legend

IDL - Instrument Detection Limit.

ND - Not Detected.

Notes:

(1) The indicated IDL for each analyte is equal to or less than the CRQL.

(2) Frequency of detection refers to the number of locations an analyte was detected versus the total number of locations sampled on that segment.

No Phase II RI surface water semi-volatile organic samples were collected along Main Soldier Creek due to low concentrations indicated by the Phase I analytical results.

4.2.2.3 Surface Water Semi-Volatile Organic Results for East Soldier Creek

Locations. Thirteen locations were investigated during Phase I of the RI along East Soldier Creek. Benzoic acid, chrysene, and benzo(g,h,i)perylene were the only chemicals of potential concern detected by the Phase I analytical results. Benzoic acid was detected only at location E12 at a concentration of 0.4 ug/L. Chrysene was detected only at location E05 at a concentration of 5.0 ug/L. Benzo(g,h,i)perylene was detected only at location E05 at a concentration of 6.0 ug/L. No general trends or source of contamination for the Phase I surface water analytical results can be established. No Phase II RI surface water semi-volatile organic samples were collected along East Soldier Creek due to low concentrations indicated by the Phase I analytical results.

4.2.2.4 Surface Water Semi-Volatile Organic Results for West Soldier Creek

Locations. Eight locations were investigated during Phase I of the RI along West Soldier Creek. Two (W01, W09) of the eight locations were dry and no surface water samples were collected. Fluoranthene and pyrene were the only chemicals of potential concern detected by the Phase I analytical results. Fluoranthene and pyrene were detected at location W03 at a concentrations of 1.0 ug/L for each contaminant. No general trends or source of contamination for Phase I RI surface water semi-volatile analytical results can be established. No Phase II RI surface semi-volatile organic samples were collected along West Soldier Creek due to low concentrations indicated by the Phase I RI analytical results.

4.2.2.5 Surface Water Semi-Volatile Organic Results for A and B Tributary

Locations. Six locations were investigated during Phase I of the RI along Tributaries A and B. All the locations along tributaries A and B were dry and no surface water samples were collected. No surface water semi-volatile organic samples were collected along Tributaries A and B during Phase II of the RI.

TABLE 4-7
SURFACE WATER INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Aluminum IDL = 7.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	1/1	C01	907.0	C01	Building and construction, corrosion-resistant chemical equipment, die cast auto parts, electrical industry (power transmission lines), photoengraving plates, permanent magnets, cryogenic technology, machinery and accessory equipment.
	Phase I	11/13	M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13	82.4 to 3,850.0	M04	
	Phase I	13/13	All Locations	56.9 to 1,080.0	E10	
	Phase I	6/8	W02, W03, W04, W06, W07, W08	147.0 to 7,430.0	W03	
Arsenic IDL = 4.0 ug/L(1) Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	2/13	*105, MO6 E05, E06, E08 W03, W04	ND to 7.4	M05	Alloying additive for metals, battery grids, cable sheaths, boiler tubes. Used to make gallium arsenide for diodes and other electronic devices, doping agent in germanium and silicon solid state products, special solders, medicine.
	Phase I	3/13		ND to 6.8	E05	
	Phase I	2/8		ND to 9.8	W04	
Barium IDL = 2.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	1/1	C01 M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13 All Locations	350.0	C01	Getter alloys in vacuum tubes, deoxidizer for copper, Frary's metal, lubricant for anode rotors in x-ray tubes, spark-plug alloys.
	Phase I	11/13		8.1 to 1,900.0	M04	
	Phase I	13/13		256.0 to 590.0	E06	
	Phase I	6/8		129.0 to 1,020.0	W03	

TABLE 4-7 (CONTINUED)
SURFACE WATER INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Beryllium IDL = 1.0 ug/L(1) West Soldier Creek	Phase I	1/8	W03	ND to 1.0	W03	Structural material in space technology; nuclear reactors; source of neutrons when bombarded with alpha particles; special windows for x-ray tubes; in gyroscopes and computer parts; additive in rocket fuels; alloys.
Cadmium IDL, Phase I = 3.0 ug/L(1) IDL, Phase II = 4.0 ug/L(1) East Soldier Creek West Soldier Creek	Phase I Phase II Phase I Phase II	1/13 1/5 1/8 0/5	E08 E12 W03 ND	ND to 3.7 ND to 9.4 ND to 56.9 ND	E08 E12 W03 ND	Coatings on metals, alloys, fire protection systems, nickel-cadmium storage batteries, power transmission wire, basis of pigments used in ceramic glazes, machinery enamels, baking enamels, fungicide, photography and lithography, selenium rectifiers, electrodes for cadmium-vapor lamps and photoelectric cells.
Calcium IDL = 28.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I Phase I Phase I Phase I	1/1 11/13 13/13 6/8	C01 M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13 All Locations W02, W03, W04, W06, W07, W08	64,300.0 31,200.0 to 64,500.0 34,900.0 to 80,800.0 54,900.0 to 117,000.0	C01 M04 E05 W03	Alloying and reducing agent; deoxidizer for alloys; dehydrating oils; decarburization and desulfurization of iron and its alloys; separation of nitrogen from argon; reducing agent in preparation of chromium metal powder, thorium, zirconium, and uranium; fertilizer ingredient.

TABLE 4-7 (CONTINUED)
SURFACE WATER INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Chromium IDL, Phase I = 2.0 ug/L(1) IDL, Phase II = 7.0 ug/L(1) Background	Phase I	1/1	C01	3.8	C01	Alloying and plating, chromium-containing and stainless steels, protective coating for automotive and equipment accessories, nuclear and high-temperature research, constituent of inorganic pigments.
	Phase II	0/4	ND	ND	ND	
	Phase I	9/13	M01, M06, M07, M08, M09, M10, M11, M12, M13	ND to 41.5	M09	
	Phase II	3/3	All Locations	8.9 to 24.5	M07	
	Phase I	13/13	All Locations	11.4 to 156.0	E10	
	Phase II	5/5	All Locations	20.5 to 36.9	E03	
East Soldier Creek	Phase I	6/8	W02, W03, W04, W06, W07, W08	6.3 to 628.0	W03	
	Phase II	2/5	W03, W04	ND to 11.2	W04	
Cobalt IDL = 3.0 ug/L(1) Background	Phase I	1/1	C01	4.9	C01	Alloys electroplating ceramics, lamp filaments, catalyst, fertilizers, glass, drier in printing inks, paints and varnishes, colors, cermets.
	Phase I	11/13	M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13	5.6 to 11.0	M10	
	Phase I	10/13	E02, E05, E06, E07, E08, E09, E10, E11, E12, E13	ND to 11.2	E10	
	Phase I	5/8	W03, W04, W06, W07, W08	ND to 324.0	W03	
Main Soldier Creek	Phase I					
East Soldier Creek	Phase I					
West Soldier Creek	Phase I					

TABLE 4-7 (CONTINUED)
SURFACE WATER INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Copper IDL = 16.0 ug/L(1) East Soldier Creek West Soldier Creek	Phase I Phase I	7/13 1/8	E03, E04, E05, E06, E07, E08, E10 W03	ND to 242.0 ND to 985.0	E03 W03	Electric wiring; switches, plumbing, heating, roofing and building construction; chemical and pharmaceutical machinery; alloys; electroplated protective coatings and undercoats; cooking utensils; corrosion-resistant piping; insecticides; catalyst; antifouling paints.
Cyanide IDL = 0.54 ug/L(1) Main Soldier Creek West Soldier Creek	Phase I Phase II Phase I Phase II	1/13 1/3 1/8 0/5	M13 M09 W07 ND	ND to 18.0 ND to 10.1 ND to 18.0 ND	M13 M09 W07 ND	Extraction of gold and silver from ores, insecticides, fumigant, rodenticide, chelating compound, electroplating, heat treatment of metals, cleaning metals, manufacture of dyes and pigments.
Iron IDL = 3.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I Phase I Phase I Phase I	1/1 11/13 13/13 6/8	C01 M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13 All Locations W02, W03, W04, W06, W07, W08	1,730.0 176.0 to 4,550.0 138.0 to 1,180.0 66.9 to 8,450.0	C01 M06 E10 W03	Steels and other alloys; source of hydrogen by reaction with steam, powder metallurgy products, magnets, high-frequency cores, auto parts, medicine and dietary supplements.

TABLE 4-7 (CONTINUED)
SURFACE WATER INORGANIC ANALYTICAL SUMMARY
TINKER AFB – SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Lead IDL, Phase I = 1.0 ug/L(1) IDL, Phase II = 2.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	1/1	C01	3.9	C01	Storage batteries, gasoline additive, radiation shielding, cable covering, ammunition, chemical reaction equipment, solder and fusible alloys, vibration damping in heavy construction, foil, bearing alloys.
	Phase II	4/4	All Locations	1.4 to 6.0	C02	
	Phase I	11/13	M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13	1.1 to 22.3	M06	
	Phase II	2/3	M08, M09	ND to 3.9	M08	
	Phase I	12/13	E01, E02, E03, E05, E06, E07, E08, E09, E10, E11, E12, E13	ND to 6.8	E02	
	Phase II	4/5	E06, E11, E12, E13	ND to 4.8	E12	
	Phase I	5/8	W02, W03, W04, W07, W08	ND to 325.0	W03	
Magnesium IDL = 20.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	3/5	W03, W04, W07	ND to 34.5	W03	Aluminum alloys, powder for pyrotechnics and flash photography; production of iron, nickel, zinc, titanium, zirconium; antiknock gasoline additives; cathodic protection; reducing agent; desulfurizing iron in steel manufacture; precision instruments; optical mirrors; dry and wet batteries.
	Phase I	1/1	C01	21,600.0	C01	
	Phase I	11/13	M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13	17,900.0 to 36,300.0	M04	
	Phase I	13/13	All Locations	16,400.0 to 40,800.0	E05	
	Phase I	6/8	W02, W03, W04, W06, W07, W08	26,300.0 to 29,300.0	W03	

TABLE 4-7 (CONTINUED)
SURFACE WATER INORGANIC ANALYTICAL SUMMARY
TINKER AFB – SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Manganese IDL = 1.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	1/1	C01	1,000.0	C01	Steel and other alloys, high-purity salt for various chemical uses, purifying and scavenging agent in metal production.
	Phase I	11/13	M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13	34.3 to 3,060.0	M06	
	Phase I	13/13	All Locations	11.7 to 493.0	E10	
	Phase I	6/8	W02, W03, W04, W06, W07, W08	13.4 to 335.0	W08	
Nickel IDL = 9.0 ug/L(1) Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	8/13	M04, M07, M08, M09, M10 M11, M12, M13	ND to 18.4	M09	Alloys, electroplating protective coatings, alkaline storage battery, fuel cell electrodes, catalyst for methanation of fuel gases and hydrogenation of vegetable oils.
	Phase I	7/13	E02, E08, E09, E10, E11, E12, E13	ND to 32.6	E10	
	Phase I	2/8	W03, W04	ND to 3,560.0	W03	
Potassium IDL = 345.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	1/1	C01	921.0	C01	Heat exchange alloys, laboratory reagent, seeding of combustion gases in magnetohydrodynamic generators, component of fertilizers.
	Phase I	11/13	M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13	1,990.0 to 5,670.0	M11	
	Phase I	13/13	All Locations	1,350.0 to 6,680.0	E10	
	Phase I	6/8	W02, W03, W04, W06, W07, W08	1,090.0 to 5,360.0	W08	

TABLE 4-7 (CONTINUED)
SURFACE WATER INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Selenium IDL = 3.0 ug/L(1) Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I Phase I Phase I	6/13 10/13 3/8	M08, M09, M10, M11, M12, M13 E03, E04, E05, E06, E07, E08, E09, E10, E11, E12 W03, W04, W06	ND to 6.8 ND to 20.9 ND to 7.8	M10 E05 W03	Electronics, xerographic plates, TV cameras, photocells, magnetic computer cores, solar batteries, ceramics, rubber accelerator, catalyst, trace element in animal feeds.
Silver IDL = 2.0 ug/L(1) East Soldier Creek West Soldier Creek	Phase I Phase I	1/13 1/8	E10 W03	ND to 2.1 ND to 13.1	E10 W03	Photographic chemicals; alloys; lining vats and other equipment for chemical reaction vessels; electric conductors; silver plating; electronic equipment; sterilant; water purification; surgical cements; hydration and oxidation catalyst; solar cells; table cutlery; jewelry; dental, medical, and scientific equipment; electrical contacts; dental amalgams.
Sodium IDL = 367.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I Phase I Phase I Phase I	1/1 11/13 13/13 6/8	C01 M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13 All Locations W02, W03, W04, W06, W07, W08	21,400.0 21,100.0 to 122,000.0 16,400.0 to 130,000.0 15,100.0 to 79,400.0	C01 M07 E13 W07	Titanium reduction, catalyst, lab reagent, coolant in nuclear reactors, electric power cable, non-glare lighting for highways, radioactive forms in tracer studies and medicine, heat transfer agent in solar-powered electric generators.

TABLE 4-7 (CONTINUED)
SURFACE WATER INORGANIC ANALYTICAL SUMMARY
TINKER AFB - SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

ANALYTE	RI PHASE	FREQUENCY OF DETECTION (2)	LOCATIONS ANALYTE DETECTED	CONCENTRATION RANGE (ug/L)	MAXIMUM CONCENTRATION LOCATION	ANALYTE USAGE
Vanadium IDL = 2.0 ug/L(1) Background Main Soldier Creek East Soldier Creek	Phase I	1/1	C01	2.6	C01	Target material for x-rays, alloy steels, catalyst for sulfuric acid and synthetic rubber.
	Phase I	6/13	M01, M04, M08, M10, M11, M12	ND to 14.4	M01	
	Phase I	8/13	E01, E02, E03, E05, E06, E07, E09, E10	ND to 26.0	E07	
	Phase I	5/8	W02, W03, W06, W07, W08	ND to 67.0	W03	
Zinc IDL = 2.0 ug/L(1) Background Main Soldier Creek East Soldier Creek West Soldier Creek	Phase I	1/1	C01	24.5	C01	Alloys, galvanizing iron and other metals, electroplating, metal spraying, auto parts, electrical fuses, storage and dry cell batteries, fungicides, nutrition, roofing, gutters, engravers' plates, cable wrapping, organ
	Phase I	11/13	M01, M04, M05, M06, M07, M08, M09, M10, M11, M12, M13	4.5 to 40.8	M08	
	Phase I	13/13	All Locations	8.9 to 78.9	E01 and E02	
	Phase I	6/8	W02, W03, W04, W06, W07, W08	7.6 to 2,400.0	W03	

Legend:

IDL - Instrument Detection Limit.

ND - Not Detected.

Notes:

(1) The indicated IDL for each compound is equal to or less than the Contract Required Quantitation Limit.

(2) Frequency of detection refers to the number of locations an analyte was detected versus the total number of locations sampled on that segment.

4.2.3 Surface Water Inorganic Results

The Phase I and II surface water inorganic analytical results detected aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, nickel, potassium, selenium, silver, sodium, vanadium, and zinc. These contaminants, which are chemicals of potential concern as identified in the Risk Assessment report (BVWST, 1993a), will be discussed in this subsection.

A summary of the detected surface water inorganic analytical results is shown in Table 4-7 (pages 4-60 through 4-67). The surface water inorganic analytical results are presented on Figures 4-6 and 4-11 in Volume 2 of the RI report and Tables B-72 (pages B-88 through B-89) and B-90 through B-106 (pages B-107 through B-123) of Appendix B (Volume 3).

4.2.3.1 Surface Water Inorganic Results for Background Locations. Four background samples were collected at off-base locations C01, C02, C03, and D01 during Phase II of the RI. Background location C01 was the only background location sampled during both Phase I and II of the RI.

At location C01, the Phase I surface water analytical results detected aluminum (907.0 ug/L), barium (350.0 ug/L), calcium (64,300 ug/L), chromium (3.8 ug/L), cobalt (4.9 ug/L), iron (1,730 ug/L), lead (3.9 ug/L), magnesium (21,600 ug/L), manganese (1,000 ug/L), potassium (921.0 ug/L), sodium (21,400 ug/L), vanadium (2.6 ug/L), and zinc (24.5 ug/L). At location C01, the Phase II surface water analytical results detected lead (2.9 ug/L).

The Phase II surface water analytical results detected lead at location C02 (3.8 ug/L and 6.0 ug/L), C03 (1.4 ug/L), and D01 (2.7 ug/L).

4.2.3.2 Surface Water Inorganic Results for Main Soldier Creek Locations.

Thirteen locations were investigated during Phase I of the RI along Main Soldier Creek. The inorganic surface water analytical results for these thirteen locations detected concentrations of aluminum, arsenic, barium, calcium, chromium, cobalt, cyanide, iron, lead, magnesium, manganese, nickel, potassium, selenium, sodium, vanadium, and zinc. Aluminum was detected at eleven of the thirteen locations (all except M02 and M03) at concentrations ranging from 82.4 ug/L (M10) to 3,850 ug/L

(M04). Arsenic was detected at two (M05, M06) of the thirteen locations at concentrations ranging from not detected to 7.4 ug/L (M05). Barium was detected at eleven of the thirteen locations (all except M02 and M03) at concentrations ranging from 8.1 ug/L (M05) to 1,900 ug/L (M04). Calcium was detected at eleven of the thirteen locations (all except M02 and M03) at concentrations ranging from 31,200 ug/L (M01) to 64,500 ug/L (M04). Chromium was detected at nine (M01, M06, M07, M08, M09, M10, M11, M12, M13) of thirteen locations at concentrations ranging from not detected to 41.5 ug/L (M09). Cobalt was detected at all locations except M02 and M03 at concentrations ranging from 5.6 ug/L (M08) to 11.0 ug/L (M10). Cyanide was detected only at location M13 at a concentration of 18.0 ug/L. Iron was detected at all locations except M02 and M03 at concentrations ranging from 176.0 ug/L (M07) to 4,550 ug/L (M06). Lead was detected at eleven of the thirteen locations (all except M02 and M03) at concentrations ranging from 1.1 ug/L (M08) to 22.3 ug/L (M06). Magnesium was detected at all locations except M02 and M03 at concentrations ranging from 17,900 ug/L (M06) to 36,300 ug/L (M04). Manganese was detected at all locations except M02 and M03 at concentrations ranging from 34.3 ug/L (M01) to 3,060 ug/L (M06). Nickel was detected at eight (M04, M07, M08, M09, M10, M11, M12, M13) of the thirteen locations, ranging from not detected to 18.4 ug/L (M08). Potassium was detected at all locations except M02 and M03 at concentrations ranging from 1,990 ug/L (M04) to 5,670 ug/L (M11). Selenium was detected at six (M08, M09, M10, M11, M12, M13) of thirteen locations at concentrations ranging from not detected to 6.8 ug/l (M10). Sodium was detected at all locations except M02 and M03 at concentrations ranging from 21,100 ug/L (M04) to 122,000 ug/L (M07). Vanadium was detected at six (M01, M04, M08, M10, M11, M12) of the thirteen locations at concentrations ranging from not detected to 14.4 ug/L (M01). Zinc was detected at all locations except M02 and M03 at concentrations ranging from 4.5 ug/L (M05) to 40.8 ug/L (M08). It should be noted that locations M02 and M03 contained no water during the Phase I field investigation. Based on the Risk Assessment report, the Phase I analytical results for Main Soldier Creek were at concentrations consistent with background (BVWST, 1993a).

Three locations (M07, M08, and M09) were investigated during Phase II of the RI along Main Soldier Creek. These locations were investigated further due to the relatively higher levels of chemicals of potential concern detected in the Phase I samples. The Phase II RI inorganic analytical results for these three locations

detected concentrations for chromium, cyanide, and lead. Chromium was detected at all three locations (M07, M08, M09) at concentrations of 24.5 ug/L, 21.9 ug/L, and 8.9 ug/L, respectively. Cyanide was detected at one location (M09) at a concentration of 10.1 ug/L. Lead was detected at two (M08, M09) of three locations at concentrations of 3.9 ug/L and 2.5 ug/L, respectively. Although these concentrations represent decreasing values further downstream, no other general trends for chromium and lead can be concluded based on the available data for Main Soldier Creek.

4.2.3.3 Surface Water Inorganic Results for East Soldier Creek Locations.

Thirteen locations were investigated during Phase I of the RI along East Soldier Creek. The surface water inorganic analytical results detected concentrations of aluminum, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, silver, sodium, vanadium, and zinc. Aluminum was detected at all locations at concentrations ranging from 56.9 ug/L (E11) to 1,080 ug/L (E10). Arsenic was detected at three (E05, E06, E08) of the thirteen locations at concentrations ranging from not detected to 6.8 ug/L (E05). Barium was detected at all locations, ranging from 256.0 ug/L (E13) to 590.0 ug/L (E06). Cadmium was detected only at location E08 at a concentration of 3.7 ug/L. Calcium was detected at all locations at concentrations ranging from 34,900 ug/L (E03) to 80,800 ug/L (E05). Chromium was detected at all locations at concentrations ranging from 11.4 ug/L (E01) to 156.0 ug/L (E10). Cobalt was detected at ten (E02, E05, E06, E07, E08, E09, E10, E11, E12, E13) of thirteen locations at concentrations ranging from not detected to 11.2 ug/L (E10). Copper was detected at seven (E03, E04, E05, E06, E07, E08, E10) of thirteen locations at concentrations ranging from not detected to 242.0 ug/L (E03). Iron was detected at all locations at concentrations ranging from 138.0 ug/L (E04) to 1,180 ug/L (E10). Lead was detected at all locations except E04 at concentrations ranging from not detected to 6.8 ug/L (E02). Magnesium was detected at all locations at concentrations ranging from 16,400 ug/L (E03) to 40,800 ug/L (E05). Manganese was detected at all locations at concentrations ranging from 11.7 ug/L (E07) to 493.0 ug/L (E10). Nickel was detected at seven (E02, E08, E09, E10, E11, E12, E13) of thirteen locations at concentrations ranging from not detected to 32.6 ug/L (E10). Potassium was detected at all locations at concentrations ranging from 1,350 ug/L (E03) to 6,680 ug/L (E10). Selenium was detected at all locations except E01, E02, and E13 at

concentrations ranging from not detected to 20.9 ug/L (E05). Silver was detected only at location E10 at a concentration of 2.1 ug/L. Sodium was detected at all locations at concentrations ranging from 16,400 ug/L (E07) to 130,000 ug/L (E13). Vanadium was detected at eight (E01, E02, E03, E05, E06, E07, E09, E10) of the thirteen locations at concentrations ranging from not detected to 26.0 ug/L (E07). Zinc was detected at all locations at concentrations ranging from 8.9 ug/L (E13) to 78.9 ug/L (E01 and E02). Based on the Risk Assessment report, the Phase I analytical results for East Soldier Creek were at concentrations consistent with background (BVWST, 1993a).

Five locations (E03, E06, E11, E12, E13) were investigated during Phase II of the RI along East Soldier Creek. These locations were further investigated due to the relatively higher concentrations of the chemicals of concern detected in the Phase I RI samples. The Phase II RI inorganic analytical results for these five locations detected the presence of cadmium, chromium and lead. Cadmium was detected only at location E12 at a concentration of 9.4 ug/L. Chromium was detected at all locations, ranging from 20.5 ug/L (E06) to 36.9 ug/L (E03). Lead was detected at four (E06, E11, E12, E13) of five locations, ranging from not detected to 4.8 ug/L (E12). No general trends for cadmium, chromium, and lead can be concluded based on the available data.

4.2.3.4 Surface Water Inorganic Results for West Soldier Creek Locations.

Eight locations were investigated during Phase I of the RI along West Soldier Creek. The inorganic surface water analytical results for these eight locations detected the presence of aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, nickel, potassium, selenium, silver, vanadium, and zinc. Aluminum was detected at all locations except W01 and W09 at concentrations ranging from 147.0 ug/L (W06) to 7,430 ug/L (W03). Arsenic was detected at two (W03, W04) of the eight locations at concentrations ranging from not detected to 9.8 ug/L (W04). Barium was detected at all locations except W01 and W09 at concentrations ranging from 129.0 ug/L (W04) to 1,020 ug/L (W03). Beryllium was only detected at location W03 at a concentration of 1.0 ug/L. Cadmium was detected only at location W03 at a concentration of 56.9 ug/L. Calcium was detected at all locations except W01 and W09 at concentrations ranging from 54,900 ug/L (W06) to 117,000 ug/L (W03). Chromium was detected at all

locations except W01 and W09 at concentrations ranging from 6.3 ug/L (W04) to 628.0 ug/L (W03). Cobalt was detected at five (W03, W04, W06, W07, W08) of eight locations at concentrations ranging from not detected to 324.0 ug/L (W03). Copper was only detected at location W03 at a concentration of 985.0 ug/L (W03). Cyanide was detected only at location W07 at a concentration of 18.0 ug/L. Iron was detected at all locations except W01 and W09 at concentrations ranging from 66.9 ug/L (W06) to 8,450 ug/L (W03). Lead was detected at five (W02, W03, W04, W07, W08,) of eight locations at concentrations ranging from not detected to 325.0 ug/L (W03). Magnesium was detected at all locations except W01 and W09 at concentrations ranging from 26,300 ug/L (W04) to 29,300 ug/L (W03). Manganese was detected at all locations except W01 and W09 at concentrations ranging from 13.4 ug/L (W06) to 335.0 ug/L (W08). Nickel was detected at two (W03, W04) of the eight locations at concentrations ranging from not detected to 3,560 ug/L (W03). Potassium was detected at all locations except W01 and W09 at concentrations ranging from 1,090 ug/L (W04) to 5,360 ug/L (W08). Selenium was detected at three (W03, W04, W06) of eight locations at concentrations ranging from not detected to 7.8 (W03). Silver was detected only at location W03 at a concentration of 13.1 ug/L. Sodium was detected at all locations except W01 and W09 at concentrations ranging from 15,100 ug/L (W02) to 79,400 ug/L (W07). Vanadium was detected at five (W02, W03, W06, W07, W08) of the eight locations at concentrations ranging from not detected to 67.0 ug/L (W03). Zinc was detected at all locations except W01 and W09 at concentrations ranging from 7.6 ug/L (W08) to 2,400 ug/L (W03). It should be noted that locations W01 and W09 contained no water during the Phase I field investigation. Based on the Risk Assessment report, the Phase I analytical results for West Soldier Creek were at concentrations consistent with background (BVWST, 1993a).

Five locations (W03, W04, W06, W07, W08) were investigated during Phase II of the RI along West Soldier Creek. These locations were further investigated due to the relatively higher concentrations of the chemicals of concern detected during the Phase I investigation. The Phase II inorganic analytical results for these five locations detected the presence of chromium and lead. Chromium was detected at two (W03, W04) of the five locations, with a maximum concentration of 11.2 ug/L (W04). Lead was detected at three (W03, W04, W07) of the five locations at concentrations

ranging from not detected to 34.5 ug/L (W03). No general trends for chromium or lead can be concluded based on the available data.

4.2.3.5 Surface Water Inorganic Results for A and B Tributary Locations. Six locations were investigated during Phase I of the RI along Tributaries A and B. All locations along these tributaries were dry and no surface water samples were collected. No surface water inorganic samples were collected along Tributaries A and B during Phase II of the RI.

4.2.4 Surface Water Quality Results

Surface water samples were collected and analyzed for alkalinity, BOD₅, TOC, COD, hardness, nitrate, oil, and grease, and TSS at eight locations (C01, M05, M08, M09, M13, E07, E09, W06) during Phase I of the RI. The Phase I and II surface water quality parameter data is shown on Tables B-107 through B-123 (pages B-124 through B-140) of Appendix B (Volume 3). Alkalinity ranged from 36.0 milligrams per liter (mg/L) (M09) to 269.0 mg/L (M05). BOD₅ ranged from not detected to 3.5 mg/L (M09). TOC ranged from not detected to 13.0 mg/l (M05). COD ranged from not detected to 24.0 mg/L (M05). Hardness ranged from 179.0 mg/L (E07) to 258.0 mg/L (W06). Nitrates ranged from not detected to 7.2 mg/L (W06). Oil and grease ranged from 0.6 mg/L (C01 and W06) to 1.6 mg/L (E07). TSS ranged from 7.0 mg/L (W06) to 66.0 mg/L (M05).

Surface water samples were collected and analyzed for alkalinity, BOD₅, TOC, COD, hardness, nitrate, and TSS at 15 locations (C01, C02, C03, D01, M07, M08, M09, E03, E06, E11, E12, W03, W04, W06, W07, W08) during Phase II of the RI. Alkalinity ranged from 109.6 mg/L (C02) to 290.0 mg/L (W07). BOD₅ ranged from not detected to 27.0 mg/L (W03). TOC ranged from 2.3 mg/L (W06) to 36.0 mg/L (C02). COD ranged from not detected (W06) to 120.0 mg/L (C02). Hardness ranged from 124.0 mg/L (C02) to 384.0 mg/L (E03). Nitrates ranged from not detected to 9.4 mg/L (W07). It should be noted that the location C02 duplicate sample analytical results for hardness and nitrate appear to be anomalies in the data set and were, therefore, removed from consideration in this discussion. TSS ranged from not detected (E03) to 162.0 mg/L (W03).

4.2.5 Surface Water Field Measurement Data

As part of the Phase I and II RI field activities, surface water velocity, pH, DO, temperature, and specific conductivity were measured at all locations that contained surface water. The surface water field measurements are shown on Tables B-124 and B-125 (pages B-141 through B-143) of Appendix B (Volume 3).

During Phase I of the RI, thirty-one locations contained surface water. The velocity ranged from stagnant to 0.399 feet per second (ft/s) (E11). The volumetric flow rate ranged from stagnant to 7.92 cubic feet per second (ft³/s) (M12). The pH ranged from 6.7 (E05) to 8.0 (E02). The dissolved oxygen (DO) ranged from 2.5 parts per million (ppm) (M04) to 19.6 ppm (E02). Temperature ranged from 18.0 degrees Celsius (C) (E07) to 31.0 C (M13). Specific conductivity ranged from 350.0 micromhos per centimeter (umhos/cm) (E07 and M01) to 1,100.0 umhos/cm (E13).

During Phase II of the RI, all seventeen locations contained surface water. Velocity ranged from stagnant to 0.84 ft/s (E11). The volumetric flow rate ranged from stagnant to 11.83 ft³/s (E11). The pH ranged from 6.71 (C03) to 8.39 (W04). The DO ranged from 2.0 ppm (C03) to 18.3 ppm (M08). Temperature ranged from 21.2 C (W06) to 82.0 C (M08). Specific conductivity ranged from 250.0 umhos/cm (C02) to 960.0 umhos/cm (E11).

4.2.6 Summary of Surface Water Results

Volatile organics, semi-volatile organics, and inorganics were detected in samples along Tributaries A, B, C, and D, and East, Main, and West Soldier Creeks.

The volatile organics detected in the samples are described in Subsection 4.2.1. When the concentration of common laboratory chemicals (methylene chloride, acetone, and toluene) was less than ten times the CRQL, it was concluded that this contamination was likely due to cross-contamination. Chlorobenzene and carbon disulfide use at Tinker AFB has not been documented, therefore, these concentrations appear to be an anomaly from the general trend illustrated in the analytical data set. High volatile organic concentrations were detected on-base along East Soldier Creek and downstream of outfalls that have been documented to have discharged volatiles into East Soldier Creek (NUS, 1989). The general trend for West Soldier Creek appears to be relatively higher volatile organic concentrations on-

base than off-base. Building 3001 outfalls have been identified as a source of 1,1,1-trichloroethane, trichloroethane, tetrachloroethene, benzene, toluene, and xylene (total) (NUS, 1989). While the off-base locations are downstream of the Building 3001 outfalls, these locations range from one-half to one mile downstream of the Building 3001 outfalls and receive surface runoff from numerous off-base potential sources of contamination including a salvage yard and service station.

The semi-volatile organics detected in the samples are described in Subsection 4.2.2. No general trends or source of contamination for surface water semi-volatile organic analytical results could be established.

The inorganics detected in the samples are described in Subsection 4.2.3. No general trends for inorganic chemicals of concern were concluded. Volumetric flow rates were determined during Phase I and II of the RI. Nine and four volumetric flow rates were determined during Phase I of the RI and Phase II of the RI, respectively. The volumetric flow rates were consistent during Phase I and Phase II of the RI. In general, alkalinity, TOC, BOD₅, COD, hardness, and TSS are proportional to volumetric flow.

4.3 Groundwater Results

Phase I analytical results or data from 129 monitoring wells were used to evaluate the nature and extent of groundwater contamination at the Soldier Creek Site. The locations of these wells are shown on Figure 3-7 (page 3-15). Monitoring well construction logs and groundwater sampling procedures are presented in Appendix G (Volume 3). Previous groundwater analytical results from well nests, consisting of 39 total wells screened either in the perched aquifer, top of regional aquifer zone, or regional aquifer zone, were used from the IWTP Remedial Investigation report (Tulsa COE, 1991a). Previous groundwater analytical results from 21 well nests, consisting of 63 total wells with wells from each nest screened in the perched aquifer, top of regional aquifer zone, or regional aquifer zone, were also used from the Off-Base Groundwater Investigation Northeast of Base report (Tulsa COE, 1991b). Groundwater from eight off-base residential wells was sampled and analyzed during Phase I of the Soldier Creek remedial investigation. For the purpose of this evaluation, it is assumed that all of these off-base wells, except G02, G07, and G08,

are screened in the perched aquifer because the wells are shallow. The residential wells may not be screened in the perched aquifer; however, this cannot be determined because the boring logs of these monitoring wells are not available.

The residents around Tinker AFB obtain drinking water via the Midwest City Water District. Tinker AFB receives drinking water from deep wells that pump water from the producing zone on-base.

The groundwater analytical results from Phase I of the Soldier Creek RI and groundwater investigations are presented on Figures 4-12, 4-13, and 4-14, in Volume 2 of the RI report, and in Tables B-126 through B-129 of Appendix B (pages B-144 through B-147), Tables C-1 through C-21 of Appendix C (pages C-2 through C-22), and Tables D-1 through D-14 of Appendix D (pages D-2 through D-27). Results will be presented separately for the groundwater from the perched aquifer, top of regional aquifer zone, and regional aquifer zone in the following subsections. Whenever possible, particular locations where contaminants are detected are designated as downgradient from Tinker AFB or other facilities that are involved with activities which generate wastes similar to those detected. In general, available data makes it difficult to directly attribute groundwater contamination to a specific potential source. For example, aromatic hydrocarbons associated with gasoline contamination (BTEXs) were detected primarily in wells at the Soldier Creek Site which are downgradient from the service station on Douglas Boulevard across from Tinker AFB. However, these wells were not placed with the intention of investigating potential leaking underground storage tanks (USTs) at the service station. Therefore, the occurrence of aromatics in these wells cannot be directly attributed to the service station USTs. However, the USTs are a potential source.

4.3.1 Perched Aquifer

The presence of volatile organics, semi-volatile organics, and inorganics detected in samples collected from the perched aquifer are discussed in the following subsections. Groundwater results from monitoring well TOB-21B were used as background data in the perched aquifer. Monitoring well TOB-21B was selected as a background monitoring well because the analytical results indicated there was no groundwater contamination in this well and the hydrogeologic investigation indicated that TOB-21B appears to be outside the perched aquifer hydrogeologic influence of known on-

base contamination. Analytical results from samples collected from TOB-21B are included in Appendix C (Volume 3). A review of the background water quality in the perched aquifer in the area of Tinker AFB indicates that elevated concentrations of several heavy metals and water quality parameters exist (Tulsa COE, 1988a). For instance, the background averages of barium and chromium in the perched aquifer are 1,110 ug/L and 46 ug/L, respectively. No heavy metals; however, were detected in the sample from TOB-21B.

4.3.1.1 Volatile Organics. Volatile organic compounds detected in the groundwater from the perched aquifer include aromatics, chlorinated ethenes, chlorinated ethanes, and other volatile organic compounds. Chlorobenzene was the only aromatic detected in the perched aquifer. Chlorinated ethenes detected in the perched aquifer include trans-1,2-dichloroethene, tetrachloroethene, trichloroethene, and 1,1-dichloroethene. 1,1,1-Trichloroethane was the only chlorinated ethane detected in the perched aquifer. Methylene chloride was also detected in samples from the perched aquifer.

Chlorobenzene, the only aromatic found in the perched aquifer, was detected in well 1-11B at a concentration of 6 ug/L. This on-base well is located immediately north of the IWTP.

Chlorinated ethenes were detected in the perched aquifer in on-base wells 1-15B, 19B, and 34A, and off-base wells TOB-2B and TOB-5B. Trichloroethene was detected at a concentration range of 0.6 ug/L (TOB-2B) to 179,000 ug/L (34A). Tetrachloroethene was detected at a concentration range of 1.4 ug/L (TOB-5B) to 2,900 ug/L (34A). 1,1-Dichloroethene was detected at a concentration range of 1.66 ug/L to 73.9 ug/L (34A). Trans-1,2-dichloroethene was detected at a concentration range of 24 ug/L (34A) to 54 ug/L (1-15B).

Chlorinated ethenes are commonly used as degreasing and extraction solvents, and as intermediates in various industrial manufacturing processes. The highest concentrations of chlorinated ethenes found in the perched aquifer were detected in on-base wells in the vicinity and downgradient of Building 3001, and consisted of trichloroethene, tetrachloroethene, and 1,1-dichloroethene. Concentrations of

chlorinated ethenes in downgradient, off-base wells TOB-5B and TOB-2B were significantly lower than concentrations detected in the on-base wells.

One chlorinated ethane was detected in the perched aquifer in on-base well 19B. No off-base locations contained chlorinated ethanes. 1,1,1-Trichloroethane was detected in this well at a concentration of 2 ug/L. Chlorinated ethanes are also commonly used as degreasing and extraction solvents, as well as intermediates in chemical synthesis. Well 19B is downgradient of Building 3001.

Methylene chloride was also detected in the perched aquifer. Methylene chloride was detected in on-base wells 1-1B, 1-10B, 1-11B, and 1-15B at a concentration range of 2 ug/L (1-1B) to 84 ug/L (1-15B). Methylene chloride was also detected in off-base well TOB-11B at a concentration of 1.01 ug/L, and off-base residential well G06 at a concentration of 14 ug/L. Methylene chloride was detected in blank samples associated with wells 1-10B, 1-11B, and 1-15B. Methylene chloride was detected in wells that are east and downgradient of Building 3001, except for residential well G06 which is located at Douglas Boulevard and Southeast 15th Street. Because of the relatively low concentrations of methylene chloride in samples from the perched aquifer and their presence in the blank samples indicated above, these compounds, at all concentrations, were discounted as laboratory contaminants for risk assessment calculations (BVWST, 1993a).

4.3.1.2 Semi-Volatile Organics. Semi-volatile organic compounds detected in the groundwater from the perched aquifer include bis(2-ethylhexyl)phthalate (BEHP), di-n-octylphthalate, and butylbenzylphthalate. These compounds were detected in on-base and off-base wells.

BEHP was detected in on-base wells 1-11B and 19B at concentrations of 10 ug/L and 2 ug/L, respectively, and in off-base wells TOB-2B, TOB-3B, TOB-5B, and TOB-21B at a concentration range of 9 ug/L (TOB-3B) to 250 ug/L (TOB-5B). BEHP was also detected in off-base residential well G05 at a concentration of 2 ug/L. Di-n-octylphthalate was detected in off-base well TOB-2B at a concentration of 33 ug/L. Butylbenzylphthalate was detected in off-base well TOB-21B at a concentration of 10.5 ug/L.

Perched aquifer wells which contain BEHP are scattered across the Soldier Creek Site. On-base wells around the IWTP and downgradient from the groundwater high in the perched aquifer contained most of the BEHP concentrations detected. Several downgradient off-base wells to the north of Tinker AFB contained BEHP.

4.3.1.3 Inorganics. Inorganic compounds detected in the groundwater from the perched aquifer include arsenic, barium, chromium, copper, lead, nickel, selenium, and mercury. These compounds were detected in on-base wells and off-base residential wells. The off-base residential wells were also analyzed for, and contained, aluminum, calcium, cobalt, iron, magnesium, manganese, sodium, vanadium, and zinc. All of these detected chemicals were considered chemicals of potential concern in the perched aquifer at the Soldier Creek Site. All but barium, lead, nickel, and selenium were detected at concentrations consistent with background levels in the regional groundwater system (Tulsa COE, 1991a). Arsenic, barium, chromium, copper, lead, nickel, and selenium were evaluated as chemicals of potential concern in the Soldier Creek Site Risk Assessment report (BVWST, 1993a).

Arsenic was detected in off-base wells TOB-2B, TOB-8B, and TOB-9B at concentrations of 1.3 ug/L, 3.3 ug/L, and 1.5 ug/L, respectively. These wells are located north of Tinker AFB. Arsenic was not detected in any on-base wells or off-base residential wells.

Barium was detected in all on-base monitoring wells in the perched aquifer at a concentration range of 14 ug/L (34A) to 783 ug/L (1-10B). Barium was also detected in all off-base wells except TOB-1B and TOB-22B, which were dry at the time of sampling, and TOB-21B, which is the perched aquifer background well. The concentration range of barium in off-base wells was 71 ug/L (TOB-6B) to 1,610 ug/L (TOB-3B). The concentration range of barium in the off-base residential wells was 167 ug/L (G03, filtered sample) to 1,040 ug/L (G05). Highest concentrations occurred in wells to the northwest of Building 3001. The occurrence of barium above the federal MCL (1,000 ug/L) is not uncommon for wells in the Garber and Wellington formations. This formation is naturally high in barium. As part of the groundwater assessment at Tinker AFB, background water quality was determined by sampling wells upgradient to Tinker AFB and calculating an average value of groundwater quality. This groundwater data is summarized in the Building 3001 Remedial Investigation report (Tulsa COE, 1988a). The calculated values for barium were 1,110 ug/L for the perched aquifer and 663 ug/L for the regional aquifer.

Chromium was detected in on-base wells 19B, 34A, 35A, 1-15B, and 1-60B at a concentration range of 11 ug/L (35A) to 128,000 ug/L (34A), and in off-base wells TOB-5B and TOB-8B at concentrations of 36 ug/L and 17 ug/L, respectively. Chromium was detected in on-base wells under and downgradient (east) of Building 3001. The off-base detections were located north of Tinker AFB. Chromium was not detected in any residential wells.

Copper was detected in off-base wells TOB-2B, TOB-4B, TOB-5B, and TOB-8B at a concentration range of 10 ug/L (TOB-4B) to 52 ug/L (TOB-8B), and in residential well G04 at a concentration of 27 ug/L. These wells are located north and southeast of Tinker AFB. Copper was not detected in any on-base wells.

Lead was not detected in any on-base wells. Lead was detected at a concentration of 26 ug/L in off-base wells TOB-2B and TOB-4B. Lead was detected in off-base residential well G04 at a concentration of 2.7 ug/L (filtered sample).

Nickel was not detected in any on-base wells. Nickel was detected in off-base wells TOB-2B, TOB-5B, and TOB-8B at a concentration range of 18 ug/L (TOB-8B) to 30 ug/L (TOB-5B). Nickel was also detected in off-base residential well G01 at a concentration of 24.6 ug/L. The off-base nickel detections occurred in wells which are downgradient from the groundwater mound in the perched aquifer.

Selenium was not detected in any of the on-base wells in the perched aquifer. Selenium was detected in off-base wells TOB-4B, TOB-6B, TOB-7B, and TOB-9B at a concentration range of 1.3 ug/L (TOB-7B) to 9.5 ug/L (TOB-6B). The predominant occurrence of selenium was in the off-base wells to the northeast of Building 3001. These wells are screened within the groundwater mound in the perched aquifer. The background concentration of selenium was assumed to be below the detection limit (5.0 ug/L) in the Soldier Creek Site Risk Assessment (BVWST, 1993a).

4.3.2 Top of Regional Aquifer Zone

The presence of volatile organics, semi-volatile organics, and inorganics detected in samples collected from the top of regional aquifer zone are discussed in the following subsections. Groundwater results from monitoring wells TOB-14A, TOB-15A, and

TOB-16A were used as background data for the top of regional aquifer zone. Monitoring wells TOB-14A, TOB-15A, and TOB-16A were selected as background monitoring wells because analytical results from samples from these wells indicated no detected groundwater contamination and the hydrogeologic investigation indicated that monitoring wells TOB-14A, TOB-15A, and TOB-16A appear to be outside the top of regional aquifer zone hydrogeologic influence of known on-base contamination.

4.3.2.1 Volatile Organics. Volatile organic compounds detected in the top of regional aquifer zone include aromatics, chlorinated ethenes, chlorinated ethanes, and other volatile organic compounds. Aromatics detected include benzene, chlorobenzene, ethylbenzene, 1,2,4-trimethylbenzene, toluene, and xylene (total). Chlorinated ethenes detected include cis- and trans-1,2-dichloroethene, tetrachloroethene, trichloroethene, 1,1-dichloroethene, and vinyl chloride. Chlorinated ethanes detected include 1,1,1-trichloroethane, 1,1-dichloroethane, and chloroform. Other volatile organic compounds detected include acetone, methylene chloride, and 1,2-dichloropropane.

All of the aromatic hydrocarbons detected in samples from the top of regional aquifer zone were found only in off-base wells, except chlorobenzene which was detected in both on-base and off-base wells. Benzene was detected in off-base wells TOB-6A, TOB-13A, TOB-13B, TOB-20A, and TOB-20B at a concentration range of 0.7 ug/L (TOB-6A) to 5.8 ug/L (TOB-13A). Chlorobenzene was detected in on-base wells 1-11A, 1-15A, 34B, 1-49A, 1-50A, 1-50B, 1-51A, 1-51B, 1-52A, and 1-59A at a concentration range of 10 ug/L (1-59A) to 1,100 ug/L (1-50A). Chlorobenzene was detected in off-base wells TOB-12B, TOB-20A, and TOB-20B at concentrations of 27.1 ug/L, 2.54 ug/L, and 82.6 ug/L, respectively. Ethylbenzene was detected in off-base wells TOB-13A, TOB-13B, TOB-17B, and TOB-20A at concentrations of 6.1 ug/L, 4.1 ug/L, 0.6 ug/L, and 2.10 ug/L, respectively. 1,2,4-Trimethylbenzene was detected in off-base monitoring wells TOB-4A, TOB-8A, TOB-13A, and TOB-13B at concentrations of 0.1 ug/L, 0.66 ug/L, 6.52 ug/L and 2.8 ug/L, respectively. Toluene was detected in off-base wells TOB-2A, TOB-3A, TOB-5A, TOB-6A, TOB-11A, TOB-13A, TOB-13B, TOB-17A, TOB-19A, TOB-20A, and TOB-21A at a concentration range of 0.4 ug/L (TOB-6A) to 27.4 ug/L (TOB-13A). o-Xylene was detected in off-base wells TOB-4A, TOB-13A, TOB-13B, and TOB-20B at concentrations of 0.1 ug/L, 13.2 ug/L, 2.5 ug/L, and 1.91 ug/L, respectively. m-Xylene

was detected in off-base wells TOB-4A, TOB-13A, TOB-20A, and TOB-20B at concentrations of 0.1 ug/L, 11.6 ug/L, 5.27 ug/L, and 1.03 ug/L, respectively. p-Xylene was detected in off-base well TOB-20A at a concentration of 3.5 ug/L.

Only off-base wells TOB-13A and TOB-20A contained all of the aromatic hydrocarbons detected in the top of regional aquifer zones. Both of these well locations are downgradient from Tinker AFB and the service station located on Douglas Boulevard between Tinker AFB and the wells. Aromatic hydrocarbons, especially benzene, toluene, ethylbenzene, and xylene (total), are typical contaminants associated with gasoline. However, the occurrence of aromatics at these locations cannot be directly attributed to either, or both of these locations based on the available data. Most of the toluene detections occurred in the off-base wells north of Building 3001 and the storage tank area at the northwest corner of Building 3001. The concentrations of toluene north of the storage tank area were relatively low. The highest concentrations of toluene were detected in wells TOB-13A and TOB-20A. Most of the other aromatic hydrocarbons detected in the top of regional aquifer zone occurred on-base and off-base in the northeast portions of Tinker AFB, downgradient from the groundwater high under East Soldier Creek.

Chlorinated ethenes were detected in samples from the top of regional aquifer zone in on-base wells 1-1A, 1-11A, 1-15A, 19A, 34B, 1-49A, 1-49B, 1-50A, 1-50B, 1-51A, 1-51B, 1-59A, and 1-60A, and off-base wells TOB-4A, TOB-6A, TOB-9A, TOB-13A, TOB-15A, TOB-20A, and TOB-20B. In general, concentrations were much higher in the on-base wells than in the off-base wells. Trichloroethene was detected in on-base wells at a concentration range of 2 ug/L (1-51B) to 18,000 ug/L (34B). The concentration range of trichloroethene in off-base wells was 0.1 ug/L (TOB-4A) to 12 ug/L (TOB-6A). Tetrachloroethene was detected in on-base wells at a concentration range of not detected (1-51B) to 920 ug/L (1-11A). Tetrachloroethene was detected in off-base wells TOB-6A, TOB-9A, and TOB-15A at concentrations of 0.2 ug/L, 1.02 ug/L, and 1.4 ug/L, respectively. Trans-1,2-dichloroethene was detected in on-base wells at a concentration range of 3 ug/L (1-51B) to 2,161 ug/L (1-51A). Trans-1,2-dichloroethene was detected in off-base wells TOB-4A, TOB-6A, and TOB-20A at concentrations of 0.3 ug/L, 0.4 ug/L, and 1.6 ug/L, respectively. Vinyl chloride was detected in on-base wells at a concentration range of 7 ug/L (1-59A) to 1,615 ug/L (1-51A). Vinyl chloride was detected in off-base wells TOB-6A and TOB-

13A at concentrations of 119 ug/L and 0.80 ug/L, respectively. 1,1-Dichloroethene was detected in on-base wells at a concentration range of 6 ug/L (1-50B) to 48 ug/L (1-11A). 1,1-Dichloroethene was detected in off-base wells TOB-4A, TOB-6A, and TOB-20B at concentrations of 0.2 ug/L, 7 ug/L, and 1.66 ug/L, respectively. cis-1,2-Dichloroethene was detected in off-base wells at a concentration range of 0.76 ug/L (TOB-9A) to 9.09 ug/L (TOB-20A). The off-base residential well (G07) contained tetrachloroethene at a concentration of 2 ug/L.

The highest concentrations of chlorinated ethenes detected in samples from the top of regional aquifer zone occurred in on-base wells between Building 3001 and the IWTP. In some cases, wells in the top of regional aquifer zone that contain high concentrations of chlorinated ethenes are from well nests that also had wells screened higher in the top of regional aquifer zone or perched aquifer wells with high concentrations. For example, trichloroethene was detected in 1-15A at a concentration of 200 ug/L. Monitoring well 1-15B, which is screened in the perched aquifer, had a concentration of 720 ug/L, one of the higher concentrations in the perched aquifer. This trend exists for other volatile organics also, particularly in monitoring well nests 19 and 1-50. This pattern suggests a vertical component to contaminant migration in the vicinity of Building 3001 and the IWTP. Off-base well TOB-20B, which contained chlorinated ethenes is also downgradient from Tinker AFB. There is an automobile repair shop along Douglas Boulevard between Tinker AFB and monitoring well TOB-20B which could also be a potential source of chlorinated ethenes. The repair shop is located east of Gate 20 across Douglas Boulevard. Residential well G07 is also downgradient from Tinker AFB, but its location is adjacent to service stations, dry cleaners, and various industrial manufacturing facilities along Southeast 29th Street which could be the source of the chlorinated ethenes in this well.

Chlorinated ethanes were detected in the top of regional aquifer zone in on-base wells 1-11A, 1-15A, 19A, 1-49A, 1-49B, 1-50A, 1-50B, 1-51A, 1-51B, 1-52A, 1-52B, 1-59A, and 1-60A. The only chlorinated ethanes detected in off-base wells were chloroform and 1,1-dichloroethane. Chloroform was detected at very low concentrations in off-base wells TOB-5A, TOB-9A, and TOB-13A. The highest concentration of chloroform (2.5 ug/L) was detected in off-base well TOB-5A. The sample from well G07 contained 1,1-dichloroethane at a concentration of 14 ug/L.

1,1,1-Trichloroethane was detected in the on-base wells at a concentration range of 4 ug/L (1-60A) to 150 ug/L (19A). 1,1-Dichloroethane, which is a major degradation product of 1,1,1-trichloroethane, was detected in on-base wells at a concentration range of 2 ug/L (1-15A and 1-52A) to 178 ug/L (1-51A). The spatial distribution of chlorinated ethanes in the top of regional aquifer zone is similar to the chlorinated ethenes. Chlorinated ethane detections occurred in samples from wells located between, and downgradient of, Building 3001 and IWTP. Many of these wells are nested with other wells which also contained chlorinated ethanes. The location of residential well G07 makes correlation with a potential source difficult based on the available data. The location is downgradient from Tinker AFB and service stations, dry cleaners, and various manufacturing facilities along Southeast 29th Street, but attributing this occurrence to any or all of these sources cannot be done at this time. 1,1-Dichloroethane occurred in greater abundance and higher concentrations than 1,1,1-trichloroethane.

Other volatile organic compounds detected in samples from the top of regional aquifer zone include acetone, methylene chloride, and 1,2-dichloropropane. Acetone was only detected in off-base residential well G02 at a concentration of 16 ug/L. Methylene chloride was detected in on-base wells 22B, 1-10A, 1-15A, 1-49A, 1-49B, 1-50A, 1-50B, 1-51A, 1-52B, 1-53B, 1-59A, and 1-60A at a concentration range of 2 ug/L (1-60A) to 44 ug/L (1-51A). Methylene chloride was also detected in off-base residential well G02 at a concentration of 22 ug/L. Methylene chloride was detected in blank samples associated with wells 22B, 1-10A, 1-15A, 1-51A, 1-52B, 1-53B, 1-59A, and 1-60A. Methylene chloride is a common laboratory contaminant. 1,2-Dichloropropane was detected in on-base wells 1-50A, 1-51A, and 1-60A at concentrations of 39 ug/L, 73 ug/L, and 3 ug/L, respectively. 1,2-Dichloropropane was detected in off-base well TOB-6A at a concentration of 4 ug/L.

4.3.2.2 Semi-Volatile Organics. Semi-volatile organic compounds detected in the groundwater from the top of regional aquifer zone include 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, BEHP, di-n-butylphthalate, dimethylphthalate, di-n-octylphthalate, naphthalene, and 1,2,4-trimethylbenzene. All of the compounds, except for dimethylphthalate, were assessed as chemicals of potential concern in the Soldier Creek Site Risk Assessment report (BVWST, 1993a). Only BEHP and 1,4-

dichlorobenzene occurred at high enough concentrations to generate significant risk values.

1,2-Dichlorobenzene was detected in on-base wells 1-11A, 1-49A, 1-50A, 1-50B, and 1-52A at a concentration range of 1 ug/L (1-52A) to 420 ug/L (1-49A), and in off-base wells TOB-12B and TOB-20B at concentrations of 6.06 ug/L and 11.1 ug/L, respectively. 1,3-Dichlorobenzene was detected in off-base wells TOB-9A, TOB-12B, and TOB-20B at concentrations of 0.52 ug/L, 0.94 ug/L, and 2.8 ug/L, respectively. 1,4-Dichlorobenzene was detected in on-base wells 1-11A, 1-50A, 1-49A, 1-50B, 1-51A, and 1-52A at a concentration range of 1 ug/L (1-52A) to 220 ug/L (1-49A), and in off-base wells TOB-12B, TOB-15A, and TOB-20B at concentrations of 0.7 ug/L, 7.17 ug/L, and 17.2 ug/L, respectively.

Di-n-octylphthalate was detected at off-base wells TOB-2A, TOB-4A, TOB-5A, TOB-7A, TOB-8A, TOB-11A, TOB-13A, TOB-13B, TOB-16A, TOB-17A, TOB-18B, TOB-19A, TOB-20A, TOB-20B, and TOB-21A at a concentration range of 4 ug/L (TOB-13B) to 85 ug/L (TOB-13A). Di-n-butylphthalate was detected in off-base well TOB-20B at a concentration of 2.8 ug/L.

BEHP was detected in samples from the top of regional aquifer zone in on-base wells 19A, 22A, 22B, 1-49A, 1-50A, 1-50B, 1-51B, 1-52A, 1-53A, and 1-53B at a concentration range of 2 ug/L (19A) to 44 ug/L (1-51B). BEHP was also detected in all of the off-base wells, except TOB-9A, TOB-11B, TOB-12A, TOB-12B, TOB-14A, TOB-14B, and TOB-16B. The concentration range of BEHP in off-base wells was 2.8 ug/L (TOB-11A) to 1,100 ug/L (TOB-3A).

Several downgradient off-base wells to the northwest, northeast and east of Tinker AFB contained BEHP. On-base well 1-50B, which is downgradient of Building 3001, contained the only detected concentrations of 1,2-dichlorobenzene and 1,4-dichlorobenzene in the top of regional aquifer zone. Off-base wells TOB-12B and TOB-20B, which are downgradient of Tinker AFB and the gas station on Douglas Boulevard were the only off-base wells which contained 1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene.

4.3.2.3 Inorganics. Inorganic compounds detected in samples from the top of regional aquifer zone include arsenic, barium, chromium, copper, lead, mercury, nickel, and selenium. The Soldier Creek Site risk assessment identified arsenic, barium, chromium, copper, lead, and nickel as chemicals of potential concern (BVWST, 1993a).

Arsenic was not detected in any on-base wells or off-base residential wells. Arsenic was detected in off-base wells TOB-3A, TOB-4A, TOB-5A, TOB-9A, TOB-11A, TOB-13A, TOB-14B, TOB-15A, TOB-16B, TOB-18A, TOB-18B, TOB-19B, TOB-20A, TOB-20B, and TOB-21A at a concentration range of 11 ug/L (TOB-21A and TOB-18B) to 42 ug/L (TOB-5A).

Barium was detected in all of the on-base wells at a concentration range of 112 ug/L (34B) to 2,700 ug/L (1-50B). The highest concentrations of barium in on-base wells occurred in the vicinity of the IWTP. The highest concentrations of barium in off-base wells occurred to the northwest, north, and northeast of Tinker AFB. Barium was also detected in all of the off-base wells, except TOB-6A, TOB-8A, TOB-14A, and TOB-19A, at a concentration range of 179 ug/L (TOB-22A) to 3,460 ug/L (TOB-2A). The concentrations of barium in background wells TOB-14A, TOB-15A, and TOB-16A were not detected, less than 578 ug/L, and less than 816 ug/L, respectively.

Copper was not detected in any on-base wells. Copper was detected in off-base wells TOB-1A, TOB-2A, TOB-3A, TOB-4A, TOB-5A, TOB-11A, TOB-12B, TOB-13A, TOB-13B, TOB-16A, TOB-18B, TOB-19B, and TOB-20A at a concentration range of 11 ug/L (TOB-19B) to 39 ug/L (TOB-13A), and at off-base residential well G02 at a concentration of 41.6 ug/L.

Lead was detected in on-base well 1-52B at a concentration of 25 ug/L. Lead was detected in off-base residential wells G02 and G08 at concentrations of 5.1 ug/L and 18.3 ug/L (filtered samples), respectively. The background concentration of lead was assumed to be below the detection limit (5.0 ug/L) in the Soldier Creek Site Risk Assessment report (BVWST, 1993a).

Chromium was detected in on-base wells 1-11A, 1-15A, 19A, 34B, 1-49A, 1-49B, 1-50A, 1-51A, 1-51B, 1-52A, 1-52B, 1-53A, 1-53B, 1-59A, and 1-60A at a concentration range of 11 ug/L (1-51A) to 6,520 ug/L (34B). Chromium was also detected in off-base wells TOB-1A through TOB-5A, TOB-7A, TOB-11A, TOB-12B, TOB-13A, TOB-13B, TOB-16A, and TOB-18A at a concentration range of 10 ug/L (TOB-13A) to 46 ug/L (TOB-7A).

Nickel was detected in on-base wells 1-15B, 1-49B, 1-50B, 1-51B, and 1-53B at a concentration range of 40 ug/L (1-50B) to 305 ug/L (1-49B). Nickel was detected in off-base wells TOB-3A, TOB-4A, TOB-5A, TOB-12B, TOB-13B, and TOB-16A at a concentration range of 18 ug/L (TOB-5A) to 41 ug/L (TOB-13B). Nickel was also detected in off-base residential wells G01 and G07 at concentrations of 24.6 ug/L and 2.2 ug/L, respectively. The occurrence of nickel in on-base wells was between Building 3001, East Soldier Creek and Bradley Drive, with the highest concentration under the IWTP. The off-base nickel detections occurred north and northeast of Building 3001. The background concentration of nickel was assumed to be below the detection limit (40.0 ug/L) in the Soldier Creek Site Risk Assessment report (BVWST, 1993a). Concentrations of nickel were below this background concentration at all off-base locations except TOB-13B (41 ug/L).

Selenium was not detected in any of the on-base wells in the top of regional zone aquifer. Selenium was detected in off-base wells TOB-5A, TOB-11A, TOB-13B, TOB-15A, and TOB-20B at a concentration of 1.1 ug/L (TOB-13B) to 6.8 ug/L (TOB-20B).

4.3.3 Regional Aquifer Zone

The presence of volatile organics, semi-volatile organics, and inorganics detected in samples from the regional aquifer zone are discussed in the following subsections. In general, occurrences and concentrations of contamination were lower in the regional aquifer zone than the perched aquifer and top of regional aquifer zone. Groundwater results from monitoring wells TOB-14C, TOB-15C, and TOB-16C were used as background data for the regional aquifer zone. Monitoring wells TOC-14C, TOB-15C, and TOB-16C were selected as background monitoring wells because analytical results from samples from these wells indicated there was no groundwater contamination and the hydrogeology investigation indicated that monitoring wells

TOB-14C, TOB-15C, and TOB-16C appear to be outside the regional aquifer zone hydrogeologic influence of known on-base contamination.

4.3.3.1 Volatile Organics. Volatile organic compounds detected in samples from the regional aquifer zone include aromatics, chlorinated ethenes, chlorinated ethanes, and other volatile organic compounds. Aromatics detected in the regional aquifer zone include benzene, chlorobenzene, 1,2,4-trimethylbenzene, and toluene. Chlorinated ethenes detected in the regional aquifer zone include cis- and trans-1,2-dichloroethene, tetrachloroethene, trichloroethene, 1,1-dichloroethene, and vinyl chloride. Chlorinated ethanes detected in the regional aquifer zone include 1,1,1-trichloroethane, and 1,1-dichloroethane. Other volatile organic compounds detected in the regional aquifer zone include 1,2-dichloropropane and methylene chloride.

All of the aromatic hydrocarbons detected in the regional aquifer zone, except chlorobenzene, occurred in off-base wells. Chlorobenzene was detected in on-base wells 1-11C, 1-15C, 19C, 34C, 1-49C, 1-50C, 1-51C, 1-59C at a concentration range 2 ug/L (1-59C) to 480 ug/L (1-50C). The highest concentrations of chlorobenzene occurred in wells in the vicinity of the IWTP and Building 3001. Chlorobenzene was also detected in off-base wells TOB-6C and TOB-8C at concentrations of 40.8 ug/L and 3.98 ug/L, respectively. Toluene was detected in off-base wells TOB-3C, TOB-8C, TOB-14C, and TOB-21C at a concentration range of 0.53 ug/L (TOB-21C) to 5.02 ug/L (TOB-8C). Benzene and 1,2,4-trimethylbenzene were detected in off-base well TOB-6C at concentrations of 1.32 ug/L and 0.88 ug/L, respectively.

Most of the chlorinated ethene detections in samples from the regional aquifer zone occurred in on-base wells 1-10C, 1-11C, 1-15C, 19C, 22E, 34C, 1-49C, 1-50C, 1-51C, 1-52C, 1-53C, 1-59C, and 1-60C. Chlorinated ethenes were also detected at low concentrations in off-base wells TOB-6C and TOB-8C.

Trichloroethene was detected in the on-base wells mentioned above at a concentration range of 3 ug/L (1-52C) to 1,100 ug/L (34C). Trichloroethene was detected in off-base wells TOB-6C and TOB-8C at concentrations of 4.8 ug/L and 26.8 ug/L, respectively. trans-1,2-Dichloroethene was detected in on-base wells 1-10C, 1-11C, 1-15C, 19C, 1-50C, 1-51C, 1-52C, 1-59C, and 1-60C at a concentration range of 3 ug/L (1-10C and 1-52C) to 113 ug/L (1-59C). trans-1,2-Dichloroethene was also

detected in off-base well TOB-8C at a concentration of 0.96 ug/L. Tetrachloroethene was detected in on-base wells 1-11C, 34C, 1-49C, 1-50C, 1-59C, and 1-60C at a concentration range of 1 ug/L (1-60C) to 200 ug/L (1-50C). Tetrachloroethene was also detected in off-base well TOB-6C at a concentration of 3.96 ug/L. Vinyl chloride was detected in on-base wells 19C, 22E, 1-49C, and 1-51C at a concentration range of 6 ug/L (1-51C) to 79 ug/L (19C). Vinyl chloride was also detected in off-base well TOB-6C at a concentration of 11 ug/L. 1,1-Dichloroethene was detected in on-base wells 1-11C, 1-50C, and 1-59C at concentrations of 13 ug/L, 7 ug/L, and 24 ug/L, respectively. 1,1-Dichloroethene was detected in off-base well TOB-6C at a concentration of 3.32 ug/L. cis-1,1-Dichloroethene was detected in off-base wells TOB-6C and TOB-8C at concentrations of 13.5 ug/L and 31.5 ug/L, respectively.

Chlorinated ethene detections in the regional aquifer zone occurred in wells in the vicinity of Building 3001 and the IWTP. Most of the higher concentrations occurred in wells that are nested with wells in the perched aquifer and top of regional aquifer zone which also contained higher concentrations of chlorinated ethenes. In general, concentrations of chlorinated ethenes detected in wells from a given nest decrease from the perched aquifer to the regional aquifer zone. For example, the concentration of trichloroethene in well nest 34 decreased by an order of magnitude between the perched aquifer and the top of regional aquifer zone, and another order of magnitude between the top of regional aquifer zone and the regional aquifer zone.

Chlorinated ethanes were detected in samples from the regional aquifer zone in on-base wells 1-11C, 1-15C, 1-50C, 1-59C. None of the off-base wells contained chlorinated ethanes. 1,1,1-Trichloroethane was detected in on-base wells 1-11 C and 1-59C at concentrations of 5 ug/L and 9 ug/L, respectively. 1,1-Dichloroethane was detected in on-base wells 1-15C, 1-51C, and 1-59C at concentrations of 0.7 ug/L, 4 ug/L, and 13 ug/L, respectively.

Other volatile organic compounds detected in the regional aquifer zone include methylene chloride and 1,2-dichloropropane. Methylene chloride was detected in samples and blanks from several on-base and off-base wells. Methylene chloride is a common laboratory contaminant which was excluded from calculations in the Soldier Creek Site Risk Assessment report (BVWST, 1993a). 1,2-Dichloropropane

was detected in on-base well 1-59C at a concentration of 14 ug/L and off-base well TOB-6C at a concentration of 0.91 ug/L.

4.3.3.2 Semi-Volatile Organics. Semi-volatile organic compounds detected in samples from the regional aquifer zone include 1,2-dichlorobenzene, 1,4-dichlorobenzene, BEHP, di-n-octylphthalate, and dimethylphthalate. All of the compounds, except 1,2-dichlorobenzene and 1,4-dichlorobenzene, occurred in low concentrations, and were discounted as laboratory contaminants in the Soldier Creek Site risk assessment because of the data validation procedures completed by the Tulsa COE (Tulsa COE, 1991a).

1,2-Dichlorobenzene was detected in on-base wells 1-11C, 19C, 1-49C, and 1-50C at concentrations of 2 ug/L, 150 ug/L, 20 ug/L, and 52 ug/L, respectively. 1,4-Dichlorobenzene was also detected in on-base wells 1-11C, 19C, 1-49C, and 1-50C at concentrations of 1 ug/L, 52 ug/L, 10 ug/L, and 22 ug/L, respectively.

4.3.3.3 Inorganics. Inorganic compounds detected in samples from the regional aquifer zone include barium, lead, nickel, selenium, chromium, mercury, arsenic, and copper. All of these compounds are background constituents in the Oklahoma City groundwater system. Although all of these inorganic compounds were assessed in the Soldier Creek Site risk assessment, only barium occurred at high enough concentrations to generate significant risk values (BVWST, 1993a).

Barium was detected in all of the on-base wells at a concentration range of 16.1 ug/L (34C) to 1,360 ug/L (1-51C). Barium was also detected in all of the off-base wells, except TOB-8C, at a concentration range of 172 ug/L (TOB-1C) to 6,060 ug/L (TOB-6C). The concentrations of barium in background wells TOB-14C, TOB-15C, and TOB-16C were 281 ug/L, 405 ug/L, and 254 ug/L, respectively.

4.3.4 Summary of Groundwater Results

Volatile organics, semi-volatile organics, and inorganics were detected in samples collected from the perched aquifer, top of regional aquifer zone, and regional aquifer zone. This section summarizes the groundwater analytical results for each aquifer zone.

Volatile organics detected in samples from the perched aquifer include aromatics, chlorinated ethenes and ethanes, and other volatile organic compounds. Aromatics detected in on-base wells were typically downgradient from Tinker AFB facilities. Chlorinated ethenes and ethanes detected in samples from on-base wells in the perched aquifer were in the vicinity and downgradient of Building 3001 and the IWTP. In general, concentrations of these compounds in off-base wells were lower than concentrations in on-base wells. Semi-volatile organics detected in the perched aquifer occurred in the vicinity of the IWTP and downgradient to the northwest, north, and northeast of the groundwater high in the perched aquifer. Inorganics were detected in most of the on-base and off-base wells in the perched aquifer. Inorganics with concentrations above background levels in the perched aquifer include barium, lead, nickel, and selenium.

Volatile organics detected in samples from the top of regional aquifer zone include aromatics, chlorinated ethenes and ethanes, and other volatile organic compounds. All of the samples which contained aromatic hydrocarbons, except chlorobenzene which was also detected in on-base wells, came from off-base wells in the top of regional aquifer zone. Only two off-base wells (TOB13A and TOB20A) contained five of the six aromatic hydrocarbons detected (benzene, chlorobenzene, ethylbenzene, 1,2,4-trimethylbenzene, toluene, or xylene (total)) in the top of regional aquifer zone. Both of these wells are located downgradient of Tinker AFB and the service station on Douglas Boulevard. Most of the toluene detections occurred in samples from the off-base top of regional aquifer zone wells north of Building 3001 and the storage tank area at the northwest corner of Building 3001. The highest concentrations of chlorinated ethenes and ethanes in the top of regional aquifer zone were in samples from on-base wells between Building 3001 and the IWTP. In general, concentrations were much higher in the on-base wells than in the off-base wells. Furthermore, many of the wells in the top of regional aquifer zone that contain high concentrations of chlorinated ethenes and ethanes are from well nests that also had perched aquifer wells containing high concentrations. Semi-volatile organics were detected in samples from on-base and off-base wells. Most significant occurrences of semi-volatiles were BEHP and 1,4-dichlorobenzene. Inorganics were detected in most of the on-base and off-base wells in the top of regional aquifer zone. Barium and chromium were the only inorganics detected at concentrations high

enough to generate significant risk values in the Soldier Creek Site risk assessment (BVWST, 1993a).

In general, occurrences and concentrations of contamination were lower in the regional aquifer zone than the perched aquifer and top of regional aquifer zone. Volatile organics detected in samples from the regional aquifer zone include aromatics, chlorinated ethenes and ethanes, and other volatile organic compounds. All of the aromatics detected in the regional aquifer zone, except chlorobenzene, occurred in off-base wells. Chlorinated ethene and ethane detections in the regional aquifer zone occurred in wells in the vicinity of Building 3001 and the IWTP. Chlorinated ethanes were detected in on-base wells only. Most of the higher concentrations occurred in wells that are nested with perched aquifer and top of regional aquifer zone wells which also contained relatively higher concentrations. Detections of semi-volatile organics in the regional aquifer zone occurred in on-base wells. Inorganics were detected in most of the on-base and off-base regional aquifer zone wells. However, only barium was detected at concentrations high enough to generate significant risk values.

The EPA Maximum Contaminant Levels (MCLs) were exceeded for several organic and inorganic contaminants in both the off-base and on-base groundwater monitoring wells. The MCLs for the chemicals of potential concern at the Soldier Creek Site are presented in Table 4-8 (page 4-93). Samples from three of the residential wells exceeded the MCLs for barium (G05 and G08) or 1,2-dichloroethane (G07). The MCL for benzene was exceeded in samples from five off-base wells (TOB-13A, TOB-13B, TOB-20A, TOB-6A, and TOB-6C). The MCL for methylene chloride was exceeded in the sample from well TOB-8C, and the MCL for trichloroethene was exceeded in the samples from off-base wells TOB-6A and TOB-8C. The samples from off-base wells TOB-6A and TOB-6C exceeded the MCL for vinyl chloride. The MCL for barium was exceeded in the samples from ten off-base wells (TOB-1A, TOB-2A, TOB-2B, TOB-3B, TOB-6C, TOB-7A, TOB-7C, TOB-9C, TOB-16B, and TOB-18C). The MCL for chromium was exceeded in the samples from off-base wells TOB-3C, TOB-7C, TOB-14C, and TOB-15C. The sample from well TOB-7C exceeded the MCL for lead.

TABLE 4-8
 MAXIMUM CONTAMINANT LEVELS
 FOR GROUNDWATER CHEMICALS OF POTENTIAL
 CONCERN AT THE SOLDIER CREEK SITE
 TINKER AFB - SOLDIER CREEK RI/FS
 REMEDIAL INVESTIGATION REPORT

CHEMICAL OF POTENTIAL CONCERN	MAXIMUM CONTAMINANT LEVEL (1)
	ug/L
<u>Volatile Organics</u>	
Benzene	0
Chlorobenzene	100 (2)
Chloroform	100
1,1-Dichloroethane	100
1,1-Dichloroethene	(3)
cis-1,2-Dichloroethene	70 (2)
trans-1,2-Dichloroethene	100 (2)
1,2-Dichloropropane	5
Ethylbenzene	700
Methylene Chloride	5 (2)
Tetrachloroethene	5 (2)
Toluene	2000 (2)
1,1,1-Trichloroethane	200
Trichloroethene	5
1,2,4-Trimethylbenzene	(3)
Vinyl Chloride	2
Xylene (total)	10000
<u>Semi-volatile Organics</u>	
Bis(2-ethyl)phthalate	(3)
1,2-Dichlorobenzene	(3)
1,3-Dichlorobenzene	(3)
1,4-Dichlorobenzene	(3)
Di-n-octylphthalate	(3)
Naphthalene	(3)
<u>Inorganics</u>	
Arsenic	50
Barium	1000
Chromium	50
Copper	1000 (4)
Lead	50
Nickel	-- (3)
Selenium	50

(1) EPA, 1991.

(2) Proposed values.

(3) No Maximum Contaminant Level is available for this chemical.

(4) Secondary Maximum Contaminant Level.

The MCL for chlorobenzene was exceeded in at least one sample from each of ten on-base wells (1-11A, 1-49A, 1-49B, 1-49C, 1-50A, 1-50B, 1-50C, 1-51A, 1-51C, and 34B). At least one sample from on-base well 1-51A exceeded the MCL for 1,1-dichloroethane. The MCL for trans-1,2-dichloroethene was exceeded in at least one sample from each of thirteen wells (1-11A, 1-11C, 1-49A, 1-49C, 1-50A, 1-50B, 1-50C, 1-51A, 1-51C, 1-59C, 19A, 35B, and 35C). At least one sample from each of the on-base wells 1-11A, 1-50A, 1-50C, 1-51A, and 1-55C, exceeded the MCL for 1,2-dichloropropane. The MCL for methylene chloride was exceeded in at least one sample from each of thirty on-base wells (1-1B, 1-10A, 1-10B, 1-10C, 1-11A, 1-11B, 1-11C, 1-15A, 1-15B, 1-15C, 1-49A, 1-49B, 1-49C, 1-50A, 1-50B, 1-50C, 1-51A, 1-51B, 1-51C, 1-60A, 19A, 19B, 19C, 22C, 34A, 34B, 34C, 35A, 35B, and 72B). The MCL for tetrachloroethene was exceeded in at least one sample from each of the on-base wells 1-1A, 1-11A, 1-11C, 1-15A, 1-15B, 1-49A, 1-49B, 1-49C, 1-50A, 1-50B, 1-50C, 1-59A, 1-59C, 1-60A, 19A, 34A, 34B, 34C, and 35A. At least one sample from each of thirty on-base wells (1-1A, 1-1B, 1-10C, 1-11A, 1-11C, 1-15A, 1-15B, 1-15C, 1-49A, 1-49B, 1-49C, 1-50A, 1-50B, 1-50C, 1-51A, 1-51C, 1-53C, 1-59A, 1-59C, 1-60A, 1-60C, 19A, 19B, 19C, 34A, 34B, 34C, 35A, 35B, and 35C) exceeded the MCL for trichloroethene. The MCL for vinyl chloride was exceeded in at least one sample from each of the on-base wells 1-11A, 1-49A, 1-49C, 1-50A, 1-50B, 1-50C, 1-51A, 1-51C, 1-59A, 19C, 22C, and 34C. The MCL for barium was exceeded in at least one sample from each of fifteen on-base wells (1-15A, 1-49A, 1-49C, 1-50A, 1-50B, 1-50C, 1-51A, 1-51C, 1-53A, 1-60A, 19A, 34B, 34C, 35B, and 35C). At least one sample from each of eighteen wells (1-11A, 1-11C, 1-15B, 1-49A, 1-49B, 1-52A, 1-52C, 1-59A, 1-59C, 1-60A, 1-60C, 19B, 19C, 34A, 34B, 34C, 35B, and 35C) exceeded the MCL for chromium. The MCL for lead was exceeded in at least one sample from the on-base well 34A.

5.0 FATE AND TRANSPORT

The purpose of this section is to assess the environmental behavior of the chemicals of potential concern detected at the Soldier Creek Site. The persistence and potential for migration of the contaminants is evaluated in order to determine the potential for future presence and migration of contamination. The chemicals of potential concern for the Soldier Creek Site include volatile organics, semi-volatile organics (in the form of acid, base/neutral extractables), and the inorganics identified during Phase I and II of the investigation. Specific chemicals of concern at the Soldier Creek Site are discussed in Subsection 5.3.

A conceptual model for the Soldier Creek Site was developed at the inception of the remedial investigation workplan to facilitate understanding of past investigations, possible sources of contamination, the potential migration pathways and the potential receptors of interest (BVWST, 1990a). Following completion of the two-phased remedial investigation and analysis of the data, the conceptual model was revised to depict more accurately existing site conditions encountered during the RI. The revised conceptual model is more accurate in this RI report because of an analysis of the geologic and hydrogeologic site conditions (presented in Section 3.0) and the risk assessment model developed for the site (BVWST, 1993a) which evaluates the contaminant concentration, exposure pathway, and receptor interactions to estimate current and potential future risk at the site.

The remaining portions of this section present a summary of the possible contaminant sources and potential migration pathways at the Soldier Creek Site, followed by an analysis of the environmental behavior of the chemicals of concern onsite via these contaminant migration mechanisms, including infiltration, direct migration, erosion and runoff, advection, dispersion, retardation, volatilization, and adsorption.

5.1 Contaminant Sources

The primary potential sources of contamination at the Soldier Creek Site include on-base storage tanks and pits, on-base and off-base industrial outfalls, on-base and off-base storm drains, and on-base and off-base accidental spills. A total of 12 industrial outfalls and storm drains are known to discharge directly to East and West Soldier

Creeks on Tinker AFB (NUS, 1989). The potential sources of contamination and 12 industrial outfalls and storm drains are shown on Figure 2-1 (page 2-5). Off-base industrial outfalls and storm drains, located upstream and downstream on East and West Soldier Creek and along the main stream, discharge flows into the surrounding area. These potential on-base and off-base point sources could discharge hazardous substances and other contaminants directly into the creek. In addition, cracks or broken sections within piping could contaminate the surrounding soils and groundwater.

Accidental spills of chemical substances may occur at on-base or off-base locations within the Soldier Creek drainage system. Such spills may result in contaminant transport to Soldier Creek via surface runoff and to underlying groundwater via leaching and percolation from the soil.

Several past and current potential sources of contamination at Tinker AFB were documented in the Building 3001 RI report (Tulsa COE, 1988a) and IWTP RI report (Tulsa COE, 1991a). These sources may be indirect sources of contamination to Soldier Creek via surface runoff or groundwater discharge. The sources are listed below with a more complete discussion of each source in the above-mentioned reports.

- Underground storage tanks in the north and southwest tank areas.
- Abandoned solvent pits.
- Water supply wells.
- IWTP effluent discharge point near well cluster 1-51.
- Abandoned pits at the IWTP.
- Storm drain outfall south of the IWTP.

The Soldier Creek Site survey conducted during Phase I of the RI indicated that several potential off-base contamination sources exist, including:

- Underground gasoline storage tanks associated with the service gas station on Douglas Boulevard.
- Paint shop north of Tinker AFB.
- Salvage yard south of the Tinker Motel.

- Vacant lot north of Tinker AFB which contains dumped materials.
- Auto repair shop across from Gate 20 of Tinker AFB.

These potential sources are facilities or areas where generated wastes contain contaminants similar to those detected in the groundwater at the Soldier Creek Site. Available data makes it difficult to directly attribute groundwater contamination to any of these potential sources. For example, aromatic hydrocarbons associated with gasoline contamination (BTEXs) were detected in off-base wells TOB-17 and TOB-20 which are downgradient from the service station on Douglas Boulevard across from Tinker AFB. Monitoring wells TOB-11 and TOB-12 are in the same general area as TOB-17 and TOB-20, but benzene was not detected in either of these wells. These wells were not placed with the intention of investigating potential leaking USTs at the service station. Therefore, the occurrence of BTEXs in these wells cannot be directly attributed to the service station USTs. However, the most prevalent BTEX detections were in these wells, and the USTs are a potential source.

5.2 Potential Routes of Migration

The potential migration pathways at the Soldier Creek Site include infiltration and direct migration through surface and subsurface soil, sediment, and bedrock; groundwater transport; erosion and runoff; and interaction between site aquifers and Soldier Creek. If intrusive activities, including but not limited to excavation and disturbance of contaminated surface or subsurface materials is required during remediation, air transport mechanisms may also be considered a migration pathway.

Through infiltration, rainwater percolates downward through contaminated soils and bedrock leaching the soluble materials. The leachate continued to migrate to the water table, where migration occurs in the direction of groundwater flow. Direct contaminant migration is from spills, lagoons, buried tank, and piping systems. Because infiltration of rainwater is not required for the direct migration of wastes to the water table, higher concentrations of contaminants may be present under these circumstances; however, direct migration will require a larger release to reach the groundwater.

Once the contaminants reach the groundwater, the primary mechanisms that influence the movement of the contaminants are advection, dispersion, and retardation. Advection is the movement of the contaminants caused by the natural flow of groundwater. The velocity of a contaminant due to advection is proportional to the hydraulic gradient and the hydraulic conductivity of a geologic formation. Advection is usually the principal mechanism by which a soluble contaminant migrates downgradient.

Dispersion is the phenomenon of mixing caused by variation in size, shape, and orientation of pores, and by the velocity distribution that exists within the pores. In a porous medium, such as the layers of sandstone encountered in the subsurface at the Soldier Creek Site, the flow paths are tortuous with different flow paths having different lengths (Fetter, 1980). Dispersion has a spreading effect resulting in dilution of the contaminants. In natural flow situations, there can be dispersion both longitudinally and laterally (Fetter, 1980) with contaminants being able to follow horizontal and vertical gradients in the aquifer zones at the Soldier Creek Site. Dispersion not only occurs in the direction of advected flow but also traverses it which contributes to the dilution of contaminants.

Retardation consists of biological, physical, and chemical mechanisms that slow or inhibit the movement of contaminants, attenuate their concentrations, but result in a large volume of groundwater being contaminated. Specific types of retardation include precipitation, complexation, volatilization, degradation, transformation, and adsorption. Precipitation and complexation are chemical processes that primarily influence the movement of metals. Precipitation refers to the formation of an insoluble solid comprised of elements which were previously dissolved in water (Dragun, 1988). Complexation is a process in which a cation, typically a metal, combines with molecules or anions containing free pairs of electrons (Dragun, 1988). In most natural groundwater systems, cations exist in complex molecular or ionic forms. These complexes typically have different mobility characteristics than the lone cation. Therefore, their environmental behavior is more difficult to predict.

Volatilization is usually significant only for low molecular weight organics. Degradation and transformation can be much more significant mechanisms for organics. Degradation is split into two basic definitions - primary degradation, which

is any biologically induced structural change in an organic chemical, and ultimate degradation which is the biologically mediated degradation of an organic chemical into carbon dioxide, water, oxygen, and other inorganic products of metabolism (Dragun, 1988). Biodegradation can occur above and below the water table.

Adsorption is a significant retardation mechanism for organics in soil. Adsorption is defined as the accumulation of an element at the surface of soil particles with a decrease in the concentration of the dissolved element in water. The factors dominating this process are the solubility of contaminants, the organic carbon content of the soil, particle size, and the cation-exchange capacity.

The degree to which advection, dispersion, retardation, volatilization, and adsorption operate is affected by site geology and hydrogeology; soil, surface water, and groundwater pH; contaminant characteristics; and source characteristics.

As described in the geology and hydrogeology assessment presented in Subsections 3.3 and 3.4, respectively, the geology at the Soldier Creek Site consists of interbedded sandstone, siltstone, and shale layers overlain by a thin veneer of soil at most locations. Bedrock is exposed at some locations along East, West, and Main Soldier Creeks. Where sediments are present, they are comprised of sand, silt, and clay.

Previous investigations have focused on a conceptual model which divides groundwater at the site into two aquifers, the lower of which is divided into two zones. From shallowest to deepest, they are the perched aquifer, the top of regional zone of the Garber-Wellington, and the regional zone of the Garber-Wellington, with average depths below ground surface of 15, 30, and 110 feet respectively. The regional groundwater flow direction in the Garber-Wellington is to the southwest. Site groundwater in the perched aquifer flows semi-radially to the northwest, north, northeast, and east, from a groundwater high under Building 3001, which extends to the northeast toward the IWTP. The hydraulic conductivity of the perched aquifer is 7.6×10^{-4} cm/s (BVWST, 1991b). In the vicinity of Soldier Creek, the groundwater flows to the northwest, west, and southwest from a high centered over East Soldier Creek near its exit from the Base. As shown on the geologic sections, East Soldier Creek appears to be a recharge source for the top of regional zone. Based on slug tests and laboratory tests, the average permeability of this zone is about 9×10^{-4}

cm/sec. Because of a groundwater high in the northeast portion of the base which extends to Interstate 40, groundwater in the regional aquifer zone appears to flow to the west, east, and northeast. This groundwater high may be the result of discharge from the top of regional aquifer zone. The hydraulic conductivity in the regional aquifer zone is 3.5×10^{-4} cm/s.

The perched aquifer is on a shale layer which appears to be continuous under Building 3001 but pinches out east of East Soldier Creek. The presence of siltstone under East Soldier Creek may enhance vertical migration of water into the top of regional aquifer zone under the creek.

The top of regional aquifer zone is characterized as a semi-confined, leaky aquifer. Impermeable layers between the top of regional and regional aquifer zones are discontinuous and where an impermeable layer is not present, there is direct hydraulic connection between the aquifer zones. Groundwater flow patterns and groundwater quality data indicate that the aquifer zones interact freely. On a local scale, shale units act as vertical barriers to vertical groundwater flow but do not extend laterally for large horizontal distances allowing the water, and any contaminants, to move downward via advected flow (Tulsa COE, 1991b). The vertical flow rate in the regional aquifer zone is 40 to 50 feet per year.

Due to the complex hydrogeology known to exist within the Soldier Creek drainage system, contaminant transport may also occur via recharge and discharge between surface water and groundwater. Recharge of surface water by underlying contaminated groundwater, or recharge of underlying groundwater by contaminated surface water, may occur at various intervals and periods of time along Soldier Creek and its tributaries.

Groundwater contours and geologic cross-sections from Section 3.0 and previous investigations indicate that East Soldier Creek may be recharged from the west by groundwater during low stream flow conditions. A groundwater high in the top of regional aquifer zone beneath East Soldier Creek suggests that the creek may be recharging the top of regional aquifer zone in that area. The absence of a continuous impermeable geologic layer below East Soldier Creek indicates that the geology

below the creek may act as a conduit for creek recharge. Because Soldier Creek is a perennial stream, it also acts as a continuous runoff erosional transport mechanism.

Primary mechanisms by which contaminants enter Soldier Creek are direct discharge and inflow of contaminated groundwater from the top of regional zone. Once a contaminant enters Soldier Creek, its fate is influenced by several mechanisms. As a result of their low solubility and high vapor pressures, low molecular weight organics would be subject to degradation and rapid volatilization in the flowing creek. Contaminants may also stay in solution and flow downstream. Heavier contaminants, such as metals, may adsorb to or precipitate on the Soldier Creek sediments. The subsurface conditions in the creek sediments (Section 3.0) indicate that adsorption would retard the migration of contaminants due to the high organic content and low hydraulic conductivity of the silty clays in the creek. Residual contamination by the more strongly adsorbed compounds may remain for a significant period of time in the Soldier Creek sediments.

Although the concentrations of contaminants in the Soldier Creek surface water and sediments were low, the potential for contaminant migration from Soldier Creek through the top of regional aquifer zone was evaluated using a one-dimensional steady state analysis to determine the creek's effectiveness as a transport mechanism. The complete calculations for this evaluation are included as Appendix H (Volume 3). Assumptions used to calculate contaminant migration from Soldier Creek to the top of regional aquifer zone were as follows:

- The ground from the creek through the top of regional aquifer zone was assumed to be saturated, homogeneous, and isotropic.
- The concentration of 1,1,1-trichloroethane at the location chosen for the calculation (surface water/sediment sampling location E12) is constant.

Calculations were performed for three different scenarios. First, the concentration of 1,1,1-trichloroethane in the top of regional aquifer zone after one year was calculated. In the scenario, the concentration in the top of regional aquifer zone was 4.96 ug/L after one year. Additionally, a second scenario to evaluate migration after 10 years was evaluated. Under this second scenario, the concentration in the top of

regional aquifer zone after 10 years was 5.0 ug/L. Under the third, and final scenario, the concentration was calculated for a distance of 10 feet after one year. The third scenario calculation resulted in a concentration of 5.0 ug/L. These results are conservative because the calculations do not take into account biodegradation and volatilization, the vertical conductivity was assumed to be the same as the horizontal conductivity, and the source concentration is constant.

Contaminants that infiltrate through the cohesive Soldier Creek sediments would migrate more rapidly through the deeper sandstones, which have high hydraulic conductivities. Contaminants may migrate to the top of regional aquifer zone via recharge from East Soldier Creek and portions of Main Soldier Creek. Once they reach the top of regional aquifer zone, mobile contaminants would migrate laterally and vertically with advected groundwater flow. Through vertical advected flow, contaminants could then enter the regional aquifer zone from the top of regional aquifer zone.

Another significant groundwater transport mechanism may be direct migration from potential on-base and off-base sources into the Soldier Creek Site groundwater system. High hydraulic conductivities within the aquifer zones and high lateral and vertical flow rates within and between the aquifer zones would contribute to rapid migration of contaminants. Because of the fine grained nature of the sandstone layers encountered at Tinker AFB, filtration could be a significant retardation mechanism within the site aquifer zones. Smaller interstitial spaces within the sandstones could be clogged by colloidal material more easily than coarse grained sandstones.

5.3 Environmental Reaction of the Chemicals of Concern

The purpose of this section is to assess the environmental behavior of the most significant chemicals of concern detected at the Soldier Creek Site. This information is useful in evaluating the contaminant migration onsite and can be used with other information to develop remedial action alternatives for the feasibility study. Tables 5-1 and 5-2 (pages 5-9 and 5-10) list the chemicals of concern detected in the groundwater onsite and some of their physical and chemical parameters. The

TABLE 5-1
CHEMICALS OF CONCERN DETECTED IN THE
GROUNDWATER AT THE SOLDIER CREEK SITE
TINKER AFB – SOLDIER CREEK RI/FS
REMEDIAL INVESTIGATION REPORT

<u>Contaminant</u>	<u>Perched Aquifer</u>	<u>Top of Regional Aquifer Zone</u>	<u>Regional Aquifer Zone</u>
Benzene		X	X
Chlorobenzene		X	X
1,1–Dichloroethene	X	X	X
trans–1,2–Dichloroethene	X	X	X
1,1–Dichloroethane		X	X
1,2–Dichloropropane		X	X
Methylene Chloride		X	X
Tetrachloroethene	X	X	X
1,1,1–Trichloroethane	X	X	X
Trichloroethene	X	X	X
1,2,4–Trimethylbenzene		X	X
Vinyl Chloride		X	X
Ethylbenzene		X	
Toluene		X	
Xylene (total)		X	
cis–1,2–Dichloroethene		X	X
Chloroform		X	
1,2–Dichlorobenzene		X	X
1,3–Dichlorobenzene		X	
1,4–Dichlorobenzene		X	X
Di–n–Octylphthalate		X	
Bis(2–ethylhexyl)phthalate	X	X	
Naphthalene		X	
Barium	X	X	X
Lead	X	X	X
Arsenic	X	X	
Chromium	X	X	
Copper	X	X	
Nickel	X	X	X
Selenium	X		X

TABLE 5-2
PHYSICAL/CHEMICAL PROPERTIES OF CHEMICALS
OF POTENTIAL CONCERN DETECTED IN THE GROUNDWATER AT
THE SOLDIER CREEK SITE (1)
TINKER AFB - SOLDIER CREEK
REMEDIAL INVESTIGATION REPORT

Chemicals of Concern	Molecular Weight	Density (gm/cm(3))	Vapor Pressure ⁴ mm Hg (25C)	Water Solubility mg/L (25C)	Soil Adsorption Coefficient (Koc)	Log Octanol-Water Partition Coefficient (Log Kow)	Mobility Index
Benzene	78	0.877	95.2	1800	83	2.0	3.31
Chlorobenzene	113	1.106	11.7	500	330	2.84	1.25
trans-1,1-Dichloroethene	96.9	1.213	5.91	2250	65	2.13	4.31
1,2-Dichloropropane	112.99	1.156	49.67	2700 (@ 20C)	1.67	1.99	4.9
Methylene Chloride	84.9	1.326	425	20,000	8.8	1.3	5.98
Tetrachloroethene	165.8	1.623	17.8	150	364	2.88	0.87
1,1,1-Trichloroethane	133	1.595	96	1500	152	2.5	2.98
Trichloroethene	131.4	1.464	57.9	1100	126	2.38	2.7
Vinyl Chloride	62.5	0.911	2660	2760	57	1.38	5.11
Toluene	92	0.867	28.1	535	300	2.73	1.70
Xylene (Total)	106	0.87	10.0	198	240	303	0.92
cis-1,2-Dichloropropane	97	1.284	215	3500	39.8	1.86	1.60
1,4-Dichlorobenzene	147	1.248	1.18	79	1700	3.6	-1.26
Chloroform	119.38	1.485	159 (@ 20C)	8220 (@ 20C)	57.5 (3)	1.97	4.36
Bis(2-Ethylhexyl)Phthalate (2)	390.5	0.99	3.4x10 ⁻⁷	0.28	2455 (3)	3.6	-0.01
Barium	137	281	NA	Insoluble	NA	NA	NA
Lead	207	11.35	1.0 (@ 980C)	Insoluble	NA	NA	NA
Arsenic	74.9	5.72	NA	Insoluble	NA	NA	NA
Chromium	51.5	7.2	.0 (@ 1616C)	Insoluble	NA	NA	NA

(1) ATSDR, 1987a, 1987b, 1987c, 1988a, 1988b, 1989a, 1989b, 1989c

(2) CRC, 1979; Merck, 1983; EPA IRIS (Current 9/1/91)

(3) Value calculated from : $\log Koc = 1.00 \log Kow - 0.21$; gram per centimeter

(4) Millimeters of mercury

NA Not Available/Not Applicable

chemicals of concern in the groundwater were evaluated based on overall risk levels calculated in the Soldier Creek Site risk assessment (BVWST, 1993a). Based on the risk assessment, only contaminants in the groundwater at the Soldier Creek Site had concentrations high enough to warrant significant risk levels. Additional chemicals of concern were listed because detected concentrations exceeded levels presented in State of Oklahoma Groundwater Quality Standards. The physical/chemical parameters contribute to the environmental behavior of the compounds. Properties of the compounds, combined with physical and chemical characteristics of the site determine the fate and transport of the compounds.

The vapor pressure given in these tables is the relative measure of the volatility of a chemical when it is in equilibrium at ambient temperature and is useful in determining its rate of vaporization. The water solubility represents the maximum concentration of a chemical that will dissolve in water at ambient temperature and pressure. *Koc* is the soil adsorption coefficient normalized for the soil organic carbon content. The octanol-water partition coefficient, $\log Kow$, is an indicator of the tendency of a chemical to be dissolved in water. Compounds which have a large $\log Kow$ value are more soluble in an organic solvent than water.

The migration potential of an organic contaminant can be assessed using a calculated mobility index (MI). MI is typically used as a measure of a contaminant's relative tendency to migrate and reflects a contaminant's migration potential in water, air, and soil. It is calculated as follows:

$$MI = \log \frac{(Water\ Solubility \times Vapor\ Pressure)}{Koc}$$

Published values for *Koc* are often unavailable for many compounds; however, *Koc* values can be calculated from *Kow* values using the relationship (Dragun, 1988):

$$\log Koc = 1.00 \log Kow - 0.21$$

The following table is a general guide to the mobility index and the relative mobility of compounds.

<u>Relative Mobility Index</u>	<u>Mobility Descriptions</u>
>5.00	Extremely Mobile
0.00 to 5.00	Very Mobile
-5.00 to 0.00	Slightly Mobile
-10.00 to -5.00	Immobile
<-10.00	Very Immobile

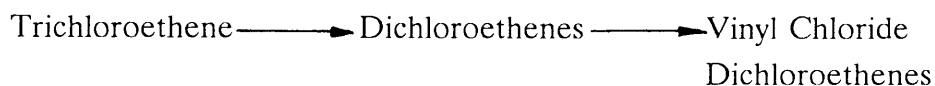
The chemicals of potential concern in the groundwater at the Soldier Creek Site can be grouped into several basic categories: volatile organic compounds, semi-volatile organic compounds, and inorganics. A discussion of the environmental fate of contaminants within each group follows.

5.3.1 Volatile Organics

Volatile organic compounds detected at the Soldier Creek Site are grouped into the broad categories of chlorinated ethenes, chlorinated ethanes, and aromatics to discuss the potential environmental fate and transport of these compounds at the site. The chlorinated ethenes and ethanes were discussed separately due to similar parent products and fate and transport characteristics.

5.3.1.1 Chlorinated Ethenes. Chlorinated ethenes including tetrachloroethene, trichloroethene, 1,1-dichloroethene, and vinyl chloride were detected in the groundwater in and around Tinker AFB. Tetrachloroethene and trichloroethene, which were detected in all three aquifer zones, are common degreasing and extraction solvents. Dichloroethenes were also detected at concentrations which generated high risk values in all three aquifer zones. Vinyl chloride had significant risk values in all three aquifer zones. Dichloroethenes and vinyl chloride are

primarily used as intermediates in various industrial manufacturing operations. The degradation breakdown sequence for chlorinated ethenes is shown below:



Tetrachloroethene (PCE) and trichloroethene (TCE) present in surface waters or on soil surfaces will predominantly volatilize. In subsurface regions, both compounds are very mobile (PCE MI = 0.87 and TCE MI = 2.7). In areas where volatilization cannot occur, tetrachloroethene and trichloroethene are only slowly degraded and may be relatively persistent. Volatilization is not a viable process for much of the tetrachloroethene transported into groundwater via leaching (ATSDR, 1987c). Biodegradation may be the most important tetrachloroethene and trichloroethene transformation process in groundwater. However, this process does not occur rapidly in the environment.

Dichloroethenes (DCE) are significantly influenced by their high volatility and the majority of DCE released to the environment partitions to the atmosphere (ATSDR, 1989a). Dichloroethenes present in surface water or on surface soils will volatilize. DCE is water soluble and has a low propensity for binding to organic or particulate matter. DCE is also very mobile, and once it enters the groundwater system, it will solubilize and migrate at the rate of advected flow. DCE is a potential anaerobic degradation product of TCE and PCE (Cline and Viste, 1984). Biotransformation is believed to be the dominant transformation process for DCE in water (ATSDR, 1989a).

Vinyl chloride released to the environment either rapidly volatilizes or migrates through or leaches from the soil to groundwater. Vinyl chloride is water soluble and extremely mobile (MI = 5.11). Once vinyl chloride enters the groundwater system, it will solubilize and migrate with advected flow. The primary loss process for vinyl chloride in surface water is volatilization. Vinyl chloride and DCE are potential anaerobic degradation products of TCE and PCE (Cline and Viste, 1984). Because vinyl chloride is carcinogenic, it has a higher associated risk than its parent products.

5.3.1.2 Chlorinated Ethanes. Chlorinated ethanes including 1,1,1-trichloroethane, 1,1-dichloroethane and chloroform were detected in the groundwater at Tinker AFB. However, only chloroform was detected in concentrations above health-based risk levels in the top of regional and regional aquifer zones, based on risk assessment calculations completed for the Soldier Creek Site (BVWST, 1993a). Chlorinated ethanes are widely used as degreasing and extraction solvents and intermediates in chemical synthesis. Chlorinated ethanes can undergo anaerobic reductive dehalogenation according to the following sequence (Cline and Viste, 1984):



1,1,1-Trichloroethane readily leaches from soil into groundwater. Volatilization is the dominant fate process from surface water and surface soil. 1,1,1-Trichloroethane is very mobile (MI = 3.08) and would migrate with advected groundwater flow. In surface water, 1,1,1-trichloroethane would not be expected to show appreciable adsorption to sediment or suspended organic material (ATSDR, 1989c).

1,1-Dichloroethane is a major product of degradation from 1,1,1-trichloroethane. 1,1-Dichloroethane in surface water is rapidly volatilized, usually before significant degradation can take place. In groundwater, 1,1-dichloroethane is very mobile (MI = 4.59) and would migrate with advected groundwater flow.

When released into surface water, volatilization is the primary fate process of chloroform (ATSDR, 1988a). When released to surface soil, it will either rapidly volatilize or readily migrate through or leach from the soil, ultimately entering the groundwater. Chloroform is very mobile (MI = 4.36) and would also readily migrate with advected groundwater flow. Once it enters the groundwater system, chloroform is very persistent, and would not easily degrade (ATSDR, 1988a).

5.3.1.3 Aromatics. Groundwater samples collected from wells at the Soldier Creek Site contained benzene, toluene, xylene, chlorobenzene, and 1,4-dichlorobenzene at concentrations which exceeded State of Oklahoma groundwater standards. These compounds, characterized as containing an aromatic or benzene ring, are common chemicals contained in fuels and used in a variety of industrial processes. They are

persistent in the environment and resist degradation due to the stability of their aromatic ring.

In general, aromatic compounds tend to be less mobile than chlorinated ethenes and ethanes. Benzene is very mobile with a mobility index of 3.31. Toluene, xylene, and chlorobenzene are very mobile with mobility indices of 1.70, 0.92, and 1.25, respectively.

The aromatic compounds tend to be significantly adsorbed in an aquifer having sufficient organic content (>0.1 percent). Aromatic compounds are also subject to biodegradation producing various intermediate breakdown products. The rate of biodegradation of aromatic compounds is difficult to predict due to wide variations over distance and time.

5.3.1.4 Other Volatile Organic Compounds. Groundwater samples collected from wells at the Soldier Creek Site contained methylene chloride and 1,2-dichloropropane at concentrations above health-based risk levels, based on risk assessment calculations for the Soldier Creek Site (BVWST, 1993a).

Methylene chloride is used primarily in aerosols, paint removers, and chemical processing. Because of its high vapor pressure, methylene chloride is expected to volatilize from surface water and near-surface soil into the atmosphere. It is probable that methylene chloride will migrate through or leach from soil into groundwater (Howard, 1990). Methylene chloride is extremely mobile (MI = 5.98) in groundwater; its degradation in groundwater is unknown.

The dominant release process for 1,2-dichloropropane in surface waters would be volatilization (ATSDR, 1989b). The *K_{oc}* value of 1,2-dichloropropane suggests that adsorption to soil, sediment, and suspended solids in water would not be significant. 1,2-Dichloropropane is very mobile (MI = 4.90) and has a tendency to be resistant to degradation and biotransformation in groundwater.

5.3.2 Semi-Volatile Organics

BEHP and 1,4-dichlorobenzene were detected in groundwater samples from the top of regional aquifer zone at concentrations above health-based risk levels, based on risk assessment calculations for the Soldier Creek Site (BVWST, 1993a). BEHP is a non-volatile, colorless liquid, only slightly soluble in water. It is widely used as a plasticizer. BEHP has a strong affinity for soils. Therefore, BEHP is not easily leached from soils by groundwater or rainwater, or from sediments by stream water. Degradation of 1,4-dichlorobenzene in aqueous systems may be carried out by microbial action (ATSDR, 1987b). Volatilization of 1,4-dichlorobenzene from surface waters occurs at a relatively rapid rate. 1,4-Dichlorobenzene is only slightly mobile with a calculated mobility index of -1.26.

5.3.3 Inorganics

Four metals (lead, arsenic, chromium, and barium) were identified as chemicals of potential concern in the groundwater at the Soldier Creek Site. All four inorganics were detected at concentrations above health-based risk levels, based on risk assessment calculations for the site (BVWST, 1993a).

Most lead present on soil particles is retained strongly to the soil, and very little is leached into surface water or groundwater. The fate of lead in soil is affected by the specific or exchange adsorption at mineral interfaces, the precipitation of sparingly soluble solid phases, and the formation of relatively stable organic-metal complexes with soil organic matter. These processes are dependent on such factors as soil pH, organic content of soil, the presence of inorganic colloids and iron oxides, ion-exchange characteristics, and the amount of lead in soil. The chemistry of lead in aqueous solution is highly complex because it can be found in a multiplicity of forms. Lead has a tendency to form compounds of low solubility with the major anions present in water. The amount of lead that remains in solution depends upon the pH of the water and the dissolved salt content. Lead is more soluble in water containing low concentrations of dissolved salts (ATSDR, 1988b).

Arsenic is present on soil predominantly as an insoluble form, however, once dissolved it is extremely mobile in groundwater and has a very complex chemistry. Arsenic is subject to oxidation-reduction, complexation, chelation, precipitation and adsorption processes. The extent to which these reactions occur depends largely on

soil pH and the redox potential (Eh) of the soil. Complexation and chelation are important processes fixing arsenic in insoluble form, but a change in pH or oxidation-reduction potential may lead to resolubilization of fixed arsenic. Leaching of arsenic is important in the top 12 inches of soil. Leaching carries arsenic deeper in sandy soils than in clay or loam soils, although EPA reports that no leached arsenic has been detected below 35 inches in any studies (ATSDR, 1987a).

Chromium is a naturally occurring metal with many commercial uses. Chromium may exist as Cr^{3+} (trivalent) or Cr^{6+} (hexavalent), of which Cr^{6+} is the more mobile form. Cr^{6+} may form complexes, but is not adsorbed significantly on to clays. Most hexavalent chromium in water with a pH above 6.5 will be present in soluble form as the chromate ion CrO_4^{2-} . The Cr^{3+} form may be precipitated as $\text{Cr}(\text{OH})_3$ or adsorbed to inorganic materials under natural conditions. Cr^{6+} can be reduced by iron, dissolved sulfides, and certain organic compounds with sulfhydryl groups, while Cr^{3+} can be oxidized by a large excess of MnO_2 and at a lower rate by oxygen under natural conditions. Moreover, if aquatic conditions favor Cr^{6+} , then chromium will accumulate as soluble forms in water; if, however, Cr^{3+} is favored, then the accumulation will occur in the sediments (EPA, 1979).

Barium is a naturally occurring metal which has many commercial uses. Barium is frequently detected in groundwater in the Oklahoma City area. Barium is a very dense metal which, like lead, has a strong affinity for soils and sediments.

6.0 RISK ASSESSMENT

This section is contained in the accompanying Risk Assessment report (BVWST, 1993a).

7.0 CONCLUSIONS AND RECOMMENDATIONS

A summary of the remedial investigation objectives met during Phase I and II of the RI and remaining data gaps and recommendations are included in the following subsections.

7.1 Remedial Investigation Conclusions

Based on risk calculations in the Soldier Creek Site Risk Assessment report (BVWST, 1993a), all surface water and sediments have associated noncarcinogenic hazard indices which indicate little concern for noncarcinogenic effects as well as little concern for carcinogenic risks. There is an increased level of concern for carcinogenic and noncarcinogenic risk for the groundwater at the Soldier Creek Site. Although the perched aquifer may indirectly recharge Soldier Creek at some locations and Soldier Creek may indirectly recharge the top of regional aquifer zone, the low concentration of contaminants detected in the Soldier Creek sediment and surface water indicate that little contamination would be introduced into any groundwater aquifer via Soldier Creek. In addition, one-dimensional steady state analysis calculations of contaminant migration from Soldier Creek to the top of regional aquifer zone indicate that contaminant transport from the creek to the groundwater would be slower compared to contaminant migration due to advective flow within the Soldier Creek Site aquifer zones. These calculations are presented in Appendix H of Volume 3 of the RI report.

Overall, the primary objectives for Phase I and II of the RI were met. The nature and extent of contamination at the Soldier Creek Site and the resulting threat posed by the release or potential release of hazardous substances to the environment has been characterized sufficiently to assess risks to human health and the environment and to develop and evaluate potential remedial alternatives during the FS process.

The following Phase I sediment objectives, established for the Tinker AFB -Soldier Creek project, and introduced in Subsection 2.1, were met by completing the Soldier Creek RI:

- Determine depth of contamination within Soldier Creek stream sediment. This objective was met by collecting sediment samples from Soldier Creek to a depth of five feet across a transect using the EWI method as discussed in Section 2.0. The results are presented in Subsection 4.1.
- Determine downstream extent of contamination within Soldier Creek which may be attributable to Tinker AFB. This objective was met by collecting sediment samples from off-base and on-base locations. The results of the Soldier Creek sediment investigation are presented in Subsection 4.1.
- Determine contaminant concentrations within Soldier Creek sediment. Sediment samples were submitted to a CLP laboratory and analyzed for volatile and semi-volatile organics on the TCL using RAS detection limits, and metals and cyanide on the TAL using RAS detection limits. Sediment contaminant concentrations are presented in Subsection 4.1.
- Determine physical and chemical characteristics of sediment for use in the development of potential remedial technologies. Sediment samples were analyzed for physical parameters including Atterberg limits, sediment particle sizes, permeability, and density. The physical/chemical results are presented in Section 4.0. Selection of potential remedial technologies was performed in the FS Initial Screening of Alternatives report (BVWST, 1993b).
- Determine sediment particle size fraction(s) which may be a transport mechanism for adsorbed contaminants. Physical descriptions of the sediment are based on visual field observations and presented in Section 3.0. Transport mechanisms are evaluated in Section 5.0.
- Assess correlation of semi-volatile organics vs. metals contamination within Soldier Creek by sample location to attempt to reduce analytical costs in the Phase II field investigation. If a correlation between semi-volatile organics and metals is determined, only selected metals analyses will be performed on samples collected in the Phase II field investigation. This objective was met from Phase I results, and only selected semi-volatile and metals analyses were performed on samples collected during the Phase II field investigation.

The analysis of the Phase I and II analytical results is presented in Section 4.0.

The following Phase II sediment objectives, established for the Tinker AFB - Soldier Creek project, and introduced in Subsection 2.1, were met by completing the Soldier Creek RI:

- Determine depth to bedrock at all Phase II sampling locations along Soldier Creek. The depth to bedrock (if within five feet of the creek bottom) was determined at most of the Phase II sediment sampling locations. The sediment depth is described in Section 3.0 and sediment sample boring logs are contained in Appendix E (Volume 3).
- Determine depth of contamination at sampling locations in Soldier Creek that potentially had concentrations above EPA's 10^{-6} (one in one million) health-based risk level, based on Phase I RI analytical results. Sediment samples were submitted to a CLP laboratory and analyzed for volatile and semi-volatile organics on the TCL using RAS detection limits, and metals and cyanide on the TAL using SAS detection limits. All analytical results were evaluated in the Soldier Creek Site Risk Assessment report (BVWST, 1993a).
- Determine sediment particle size gradation to determine potential transport mechanisms for adsorbed contaminants. Sediment particle size gradation was determined by a sieve analysis performed on granular samples. Results are presented in Sections 3.0 and 4.0.
- Determine physical/chemical characteristics of sediment for use in the development of remedial technologies. Physical/chemical characteristics of the sediment are presented in Section 4.0. Development of remedial technologies was performed in the Soldier Creek Site FS Initial Screening of Alternatives report (BVWST, 1993b).

The following Phase I RI surface water objectives, established for the Tinker AFB - Soldier Creek project, and introduced in Subsection 2.1, were met by completing the Soldier Creek RI:

- Determine the rate and volume of flow at specific locations along Soldier Creek and major tributaries from Tinker AFB. Surface water flow measurements were obtained for all Phase I sampling locations that contained water. Surface water flow measurements for the Phase I RI are discussed in Section 4.0.
- Assess potential losing and gaining segments of Soldier Creek and major tributaries from Tinker AFB using non-intrusive methods. Non-intrusive analysis included measuring stream flow rates and assessing the relationship between Soldier Creek and the Soldier Creek Site aquifers. Although an assessment could be made at some locations based on information presented in Section 3.0, the stream/aquifer relationship is dynamic and this issue remains as a data gap for many portions of the East, West, and Main Soldier Creek drainages.
- Determine contaminant concentrations within the Soldier Creek water column. Surface water samples were submitted to a CLP laboratory and analyzed for volatile and semi-volatile organics on the TCL using RAS detection limits, and metals and cyanide on the TAL using RAS detection limits. Surface water analytical results are presented in Subsection 4.2.
- Determine off-base inflow points to Soldier Creek and major tributaries from Tinker AFB which may contribute flow and/or contaminants to the stream. This objective was met during the Phase I and II field investigations; results are discussed in Section 4.0.
- Determine physical/chemical characteristics which may affect selection of potential remedial technologies. Surface water samples were analyzed for water quality parameters including alkalinity, hardness, COD, TSS, BOD₅, TOC, oil and grease, and nitrates. The surface water physical/chemical results are presented in Section 4.0. Selection of potential remedial

technologies was performed in the FS Initial Screening of Alternatives report (BVWST, 1993b).

The following Phase II surface water objectives, established for the Tinker AFB - Soldier Creek project, and introduced in Subsection 2.1, were met by completing the Soldier Creek RI:

- Determine surface water contamination concentrations at Phase II sediment sampling locations. Surface water samples were submitted to a CLP laboratory and analyzed for volatile organics on the TCL using RAS detection limits, and select metals (lead, chromium, antimony, cadmium) and cyanide on the TAL using SAS detection limits. Phase II surface water analytical results are presented in Subsection 4.2.
- Determine rate and volume of flow at Phase II sampling locations. Flow rates were measured at all Phase II locations. Surface water measurements for Phase II of the RI are discussed in Section 4.0.
- Determine water quality characteristics for use in the development of remedial technologies. Surface water samples were analyzed for water quality parameters including alkalinity, hardness, COD, TSS, BOD₅, TOC, oil and grease, and nitrates. Surface water quality characteristics are presented in Section 4.0. Selection of potential remedial technologies was performed in the FS Initial Screening of Alternatives report (BVWST, 1993b).

The following Phase I RI groundwater objectives, established for the Tinker AFB - Soldier Creek project, and introduced in Subsection 2.2, were met by completing the Soldier Creek RI:

- Determine water levels in selected existing off-base wells located within the Soldier Creek drainage basin. Water levels were measured in several existing on-base and off-base wells. Water levels and groundwater contours are presented in Section 3.0.

- Determine contaminant concentrations of groundwater collected from selected existing off-base wells. Phase I groundwater samples were submitted to a CLP laboratory and analyzed for volatile and semi-volatile organics on the TCL using RAS detection limits, and metals and cyanide on the TAL using RAS detection limits. Groundwater analytical results are presented in Subsection 4.3.
- Determine the nature and extent of contamination in groundwater, as related to Tinker AFB, from Soldier Creek. Nature and extent, as well as potential sources, of groundwater contamination are discussed in Sections 4.0 and 5.0.
- Determine the risk to public health if contamination is migrating from Soldier Creek into the groundwater at Tinker AFB. Risks to public health are assessed in the Soldier Creek Site risk assessment (BVWST, 1993a).
- Collect data necessary to perform computer modelling of groundwater associated with the Soldier Creek Site for use in preparing site feasibility studies and remedial designs. Sufficient data has been collected to generate a computer model of the Soldier Creek Site hydrogeology. The data used for such an assessment was obtained from the Phase I RI, IWTP RI Report-Tinker Air Force Base (Tulsa COE, 1991a), Building 3001 Remedial Investigation report (Tulsa COE, 1988a), and Off-Base Groundwater Investigations Northeast of Base report (Tulsa COE, 1991b).

7.2 Remedial Investigation Recommendations

The items listed in this subsection represent remaining data gaps associated with the Soldier Creek Site. Each item includes suggestions for additional activities to address the data gaps.

- The hydrogeology at the Soldier Creek Site is complex. Groundwater contouring and analysis of the site aquifer zones has been conceptual to this point. All three aquifers should be characterized in greater detail through computer modelling of the site hydrogeology. The computer model should

be calibrated to actual conditions and be used to further characterize the following:

- Groundwater analytical results from several off-base wells indicate that there is contamination in the aquifer systems off-base. During the RI, many off-base sources for contamination other than Tinker AFB were identified. Many of these potential off-base sources were discussed in Section 5.0. These potential off-base sources should be evaluated to determine their contribution, if any, to the contamination of the Soldier Creek Site groundwater, surface water, and sediments.
- Exclude groundwater underlying Soldier Creek and its drainage basin from the Soldier Creek FS and address the groundwater as a separate issue. The reason for this is two-fold. First, contaminant transport calculations indicate that very little contamination from Soldier Creek sediment is migrating downward to potentially contribute to contaminant concentrations found in the underlying top of regional aquifer zone. Second, the complexity of the hydrogeology at the Soldier Creek Site and the contribution of off-base sources to existing site contamination is not completely understood.
- Remedial technologies and alternatives associated with surface water and sediment remediation should be evaluated in the Feasibility Study Initial Screening of Alternatives report and the Feasibility Study.

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